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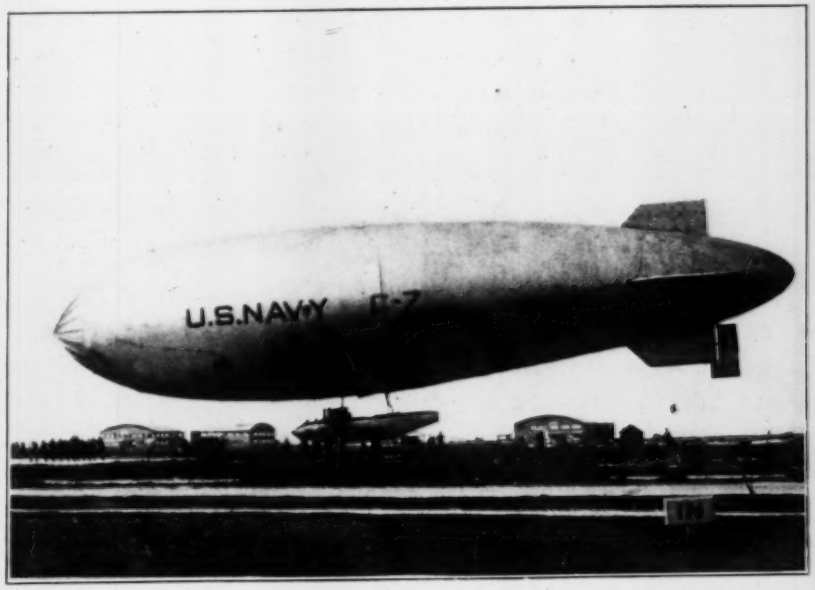
MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX



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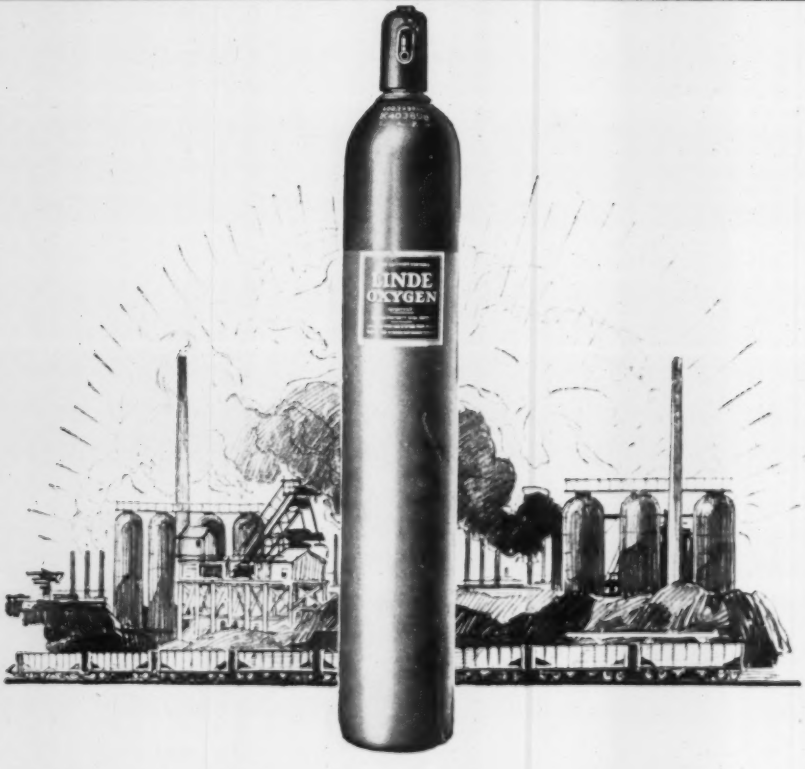
See Article in this issue on Making America Independent in the Air

SEPTEMBER 1923

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS



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Contributors to This Issue

The National Advisory Committee for Aeronautics, the results of whose work is told in this issue in Making America Independent in the Air, is composed of twelve members nominated by the President and serving without salary. To all practical purposes the Committee has charge of all the research work in aeronautics in this country of a general character, and in addition considers all aeronautical inven-

FREDERICK W. COWIE

tions submitted to the Navy. It has a laboratory of its own at Langley Memorial Field and arrangements for carrying on experimental and research work at the Bureau of Standards and the engineering departments of several universities and technical schools. The Committee issues a series of bulletins on various subjects of research and voluminous yearly accounts of the work done. It also maintains agents in several countries of Europe, who report to America the aeronautical progress abroad. Unless the matters of research are ear-marked especially confidential by the U. S. authorities, all completed research is published.

* * * * *

Frederick W. Cowie is the author of the paper on The Port of Montreal, and very fittingly too, for he is consulting engineer of the Harbor Commissioners of Montreal. He was born in Caledonia, Ontario, in 1863. He received his B.S. from McGill University in 1886 and was then appointed assistant engineer under the late Sir John Kennedy, a noted port engineer, and at that time chief engineer of the Montreal Harbor Commissioners. Since that time Mr. Cowie has continuously devoted his service to this very important branch of engineering work. Having had the advantage of training and association with Sir John Kennedy, Mr. Cowie was made consulting engineer of the Commission when the former died.

Mr. Cowie is recognized as a harbor-engineering authority and has recently been appointed as expert adviser of the Hampton Roads (State) Port Commission, where his duties will consist in aiding the State Commission to prepare a report and recommendations to the next General Assembly of Virginia, visualizing the future of Hampton Roads as a state asset.

Included in recent work Mr. Cowie has done on the Atlantic seaboard are surveys and reports with recommendations on the harbor of Boston, and a comprehensive plan on the development of Savannah as the State port of Georgia. In 1914 the Council of the Institution of Civil Engineers (Great Britain) awarded Mr. Cowie the coveted Telford gold medal for his paper on The Transportation Problems in Canada and Montreal Harbor. He is a member of the Engineering Institute of Canada.

* * * * *

Carroll R. Thompson, assistant director of the Department of Wharves, Docks, and Ferries of the City of Philadelphia, contributes an article on Material-Handling Problems in Pier Design. Mr. Thompson was born in Philadelphia, Pa., in 1885, and is

CARROLL R. THOMPSON

one of the youngest executives to fill such a position where his duties combine those of chief engineer and supervisor of new construction and the maintenance of the existing port equipment. He deserves a very considerable part of the credit for the recent rapid development of Philadelphia's waterfront facilities and the consequent growth of the port.

Mr. Thompson is well qualified to write on his subject for his previous experience includes six years with the American Bridge Co., one year with the Pennsylvania Steel Co and eleven years in the engineering office of the department in which he is now employed. While connected with this department he had unusual opportunities to become familiar with the port and terminal conditions of other seacoast cities, and has served on a number of committees to investigate and report on them. He is a member of the American Society of Civil Engineers, and of the Society of Terminal Engineers and an associate member of the American Association of Port Authorities.

* * * * *

Alfred Cotton, whose paper on The Determination of Chimney Sizes is included in this issue, was born in Southport, England, in 1871. While serving an apprenticeship from 1885 to 1892 in marine engineering, he received his technical education through university extension courses and by private tuition. He was then engaged by Thomas Henderson, of Liverpool, for whom he worked in designing mechanical stokers and grates until 1894, when he entered the Port Sunlight Soap Works of Lever Brothers, Ltd., as engineering assistant to the works manager. Here he designed one of the first, if not the first, double-stage centrifugal pumps, which operated with fairly high efficiency and entire satisfaction.

In 1898 Mr. Cotton became assistant chief engineer for Meldrum Brothers, Ltd., working on the design and adaptation of mechanical stokers and forced draft, and collaborating in the development of destructors for generating steam from municipal refuse. He came to America in 1903 and developed the Cotton furnace, which embodied a system of steam

ALFRED COTTON

jet forced draft. He manufactured and installed these furnaces and allied apparatus until the war, when he entered the employ of Colt's Patent Fire Arms Manufacturing Co. In 1918 he became chief engineer in the combustion department of the Sterling Blower Co.; and in 1919 he took his present position as chief of the research department of the Heine Boiler Co.

Coming A.S.M.E. Events

The third A.S.M.E. Regional Meeting and the first among the Southern Sections of the Society is scheduled for October 23-24, 1923, at Chattanooga, Tenn. Three technical sessions are being arranged, the first on welding, planned to give practical information to engineers and executives, the second on power problems, and the third on management. The latter is especially appropriate as the week of October 22-27 is Management Week, in which some fifty-odd A.S.M.E. Local Sections and about twenty-five sections of other societies will participate.

MECHANICAL ENGINEERING

Volume 45 September, 1923 No. 9

Making America Independent in the Air

The Inception of the National Advisory Committee for Aeronautics, Its Organization for Research, and the Results It has Achieved at the Langley Field Laboratory

WHEN the United States went into the World War in 1917 the importance of aircraft from a military point of view was fully realized, not only abroad where they had had ample experience with it, but also in this country. As a result of this realization a huge appropriation for aircraft, amounting to $640,000,000, was passed practically without discussion by Congress. To build an airplane, however, it is necessary to have money, factory facilities, raw materials, brains, and a knowledge of the laws governing the design and operation of its novel machinery.

This knowledge at that time was entirely lacking in this country and the United States had to go to England, France, and Italy and borrow from them the complete designs of the planes in which our young men were to fight the enemy. The DH-4, the Bristol, and practically all other types except training planes were all copies of foreign products, and there is good reason to believe that they were not improved in their American adaptation.

Since the armistice, however, a different spirit has appeared in American aviation. While appropriations for building airplanes by the Army and Navy have been reduced to a limit which is considered dangerous by the enthusiasts of the new service, a vast amount of research work has been done, with the result that today America may be considered as being practically independent of Europe as far as knowledge of aerodynamics and airplane design is concerned. And much of the credit for this achievement is due to the National Advisory Committee for Aeronautics.

The National Advisory Committee for Aeronautics

This body was established in 1915 for the purpose of supervising and directing the scientific study of the problems of flight with a view to their practical solution, the determination of problems which should be experimentally attacked, and their investigation and application to practical questions of the aeronautics

The Committee consists of twelve members appointed by the President. The law provides that its personnel shall consist of two members from the War Department, from the Office in Charge of Military Aeronautics; two members from the Navy Department, from the Office in Charge of Naval Aeronautics; three members representing respectively the Smithsonian Institution, the U. S. Weather Bureau, and the U. S. Bureau of Standards; and five additional members appointed by the President, all serving without compensation. These five, who may be called expert members, are Jos. S. Ames, Director of the Physical Laboratory, Johns Hopkins University, Baltimore, Md., Wm. F. Durand, Mem. A.S.M.E., Professor of Mechanical Engineering, Leland Stanford Jr. University, Cal., Samuel W. Stratton, Mem. A.S.M.E., President of the Massachusetts Institute of Technology, Cambridge, Mass., D. W. Taylor, Rear Adm. U. S. Navy, Retired, and Orville Wright, Hon. Mem. A.S.M.E., one of the two brothers who originated the airplane. These eminent and busy men could not have been induced by salary considerations to do the work of the Committee, consuming as it does a large amount of time and requiring their frequent presence in Washington, but have undertaken it from patriotic motives for the good of the country.

The task the National Advisory Committee for Aeronautics has set for itself is that of collecting the information necessary to design aircraft of all classes intelligently and to test them reliably. Only those cognizant of the deplorable lack of knowledge regarding aircraft design and operation can have any conception of the magnitude of this task, and when they are made acquainted with the achievements of the Committee they will realize how truly remarkable is the work done by its engineers, especially considering the scanty means at their disposal.

The National Advisory Committee for Aeronautics

From Left to Right:

Dr. S. W. Stratton, President, Mass. Inst. Tech.
Orville Wright, Dayton, Ohio
Major T. H. Bane, Chief Engineering Division, Army Air Service
Dr. John F. Hayford, Northwestern University
Hon. Paul Henderson, Second Asst. Postmaster General (Guest)
Rear Admiral Wm. A. Moffett, Chief, Bureau of Aeronautics, U. S. N.
Prof. Charles Marvin, Chief, United States Weather Bureau
Dr. M. I. Pupin, Columbia University
Rear Admiral D. W. Taylor, Chief Constructor, U. S. N.
Dr. Charles D. Walcott, Chairman, Secretary, Smithsonian Institution
Major General Mason M. Patrick Chief of Army Air Service
Dr. Joseph S. Ames, Chairman Executive Com., Johns Hopkins Univ.

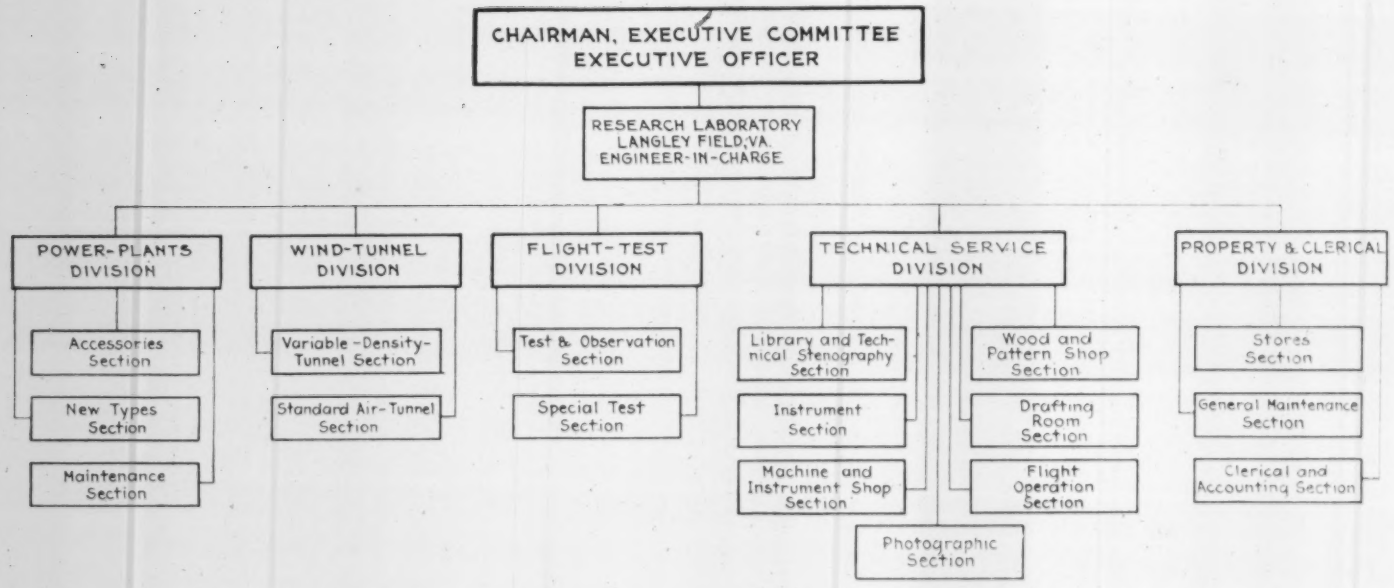

FIG. 1 RESEARCH ORGANIZATION CHART, NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

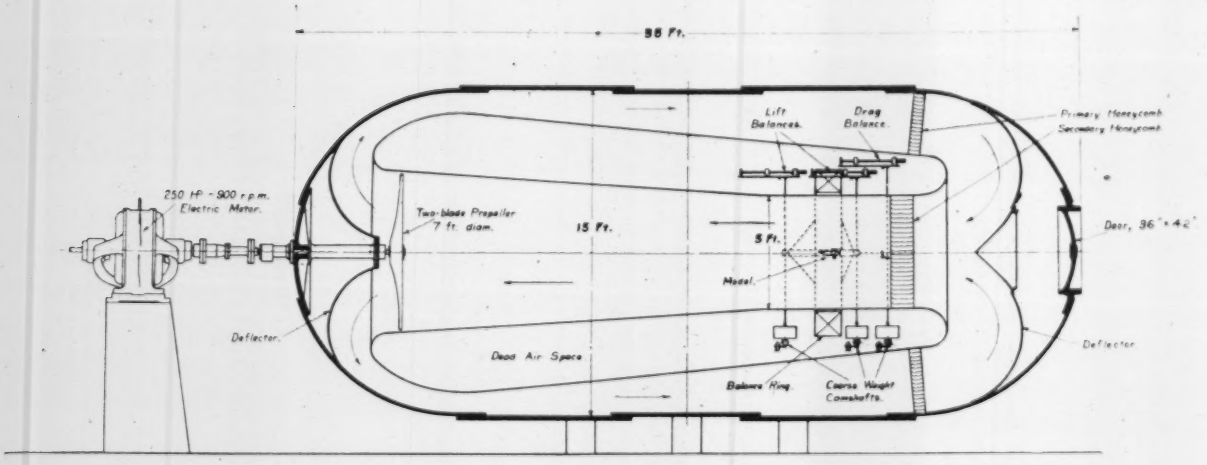

FIG. 2 LONGITUDINAL SECTION OF COMPRESSED-AIR WIND TUNNEL
(The walls are made of steel plate 2½ in. thick.)

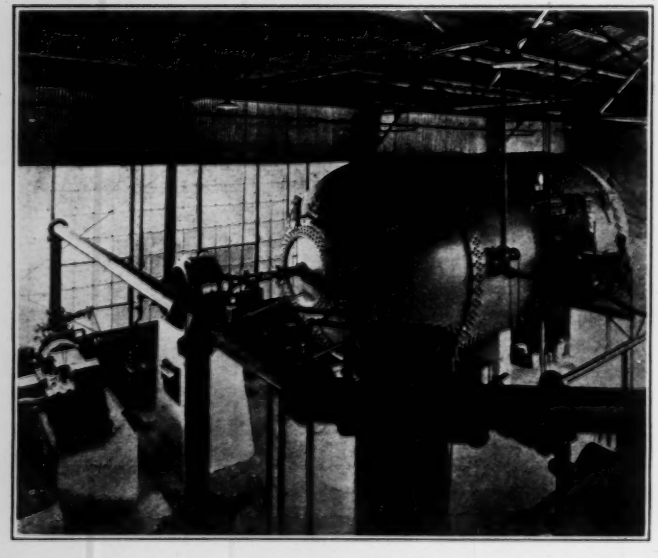

FIG. 3 VIEW OF COMPRESSED-AIR WIND TUNNEL SHOWING FAN MOTOR AND AIR PIPES

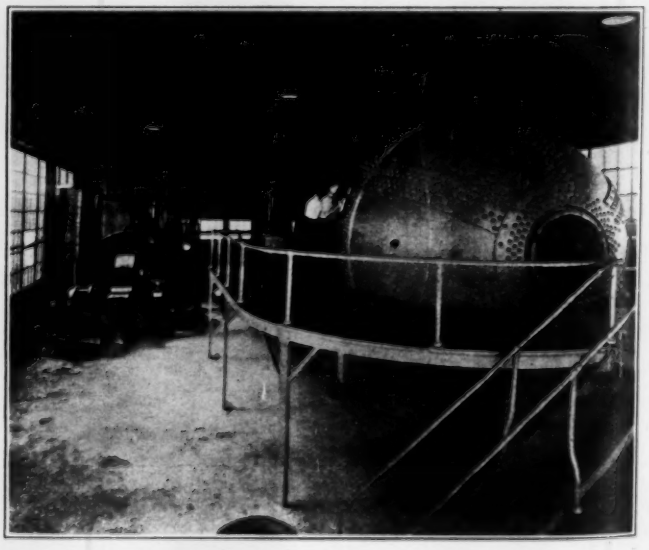

FIG. 4 COMPRESSED-AIR WIND TUNNEL SHOWING OBSERVATION PLATFORM AND AIR COMPRESSORS

THE NEW SPIRIT IN AERO ENGINEERING

The history of design in aeronautics strikingly resembles that in bridge engineering. The earliest bridges were the work of families of carpenters or stone masons who passed on a few very general and untested rules from generation to generation. They were built by certain rules of thumb without any regard to or analysis of the stresses to which they would be subjected. If the stresses happened to be within the capacity of the bridge, well and good; but if for some reason too great a load was placed on the structure, it collapsed; and while some may have become sadder they seldom became wiser through this experience, and the next bridge was built in substantially the same manner and trust reposed in Providence.

While aeronautics does not cover as many generations as bridge building, it has been but little more scientific. Airplanes were designed at first by inspiration. Sometimes this inspiration was right and a better machine resulted, but exactly why even its designer could not show. At other times inspirational design failed and the machine was abandoned, but not in many cases until it had caused the death of one or more fliers. However, there was no way of telling exactly why and in what respect the proposed design failed. To all practical purposes engineers were "wildcatting" in airplane design.

The testing of airplanes was practically as unsatisfactory as their design. Models could be tested in wind tunnels, but there was no way of determining to what extent the results of a wind-tunnel test would apply on a full-scale model, the so-called law of "dynamical similarity" being one on which entirely too little precise information is available.

In full-flight tests absolute reliance had to be placed on the

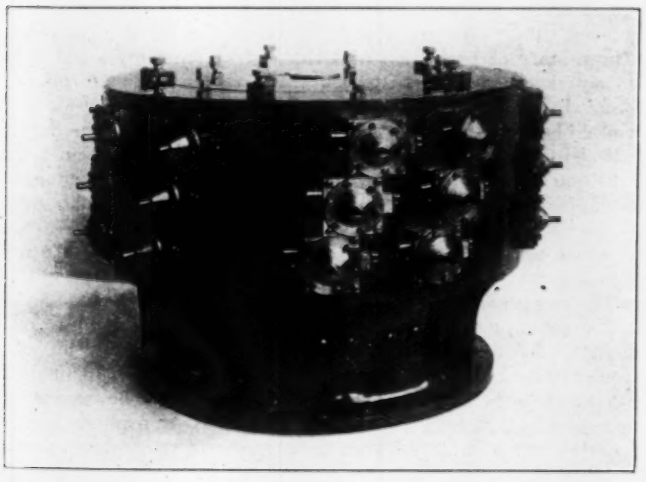

FIG. 5 MULTIPLE RECORDING MANOMETER USED IN OBTAINING THE DISTRIBUTION OF PRESSURE OVER AIRPLANE WINGS AND SURFACES OF DIRIGIBLES

impressions obtained by the test pilot, which were likely to be tinctured by his changeable state of mind, his ability to report observations exactly, and possibly his personal prejudices for or against the given design. The report of a test to all practical purposes resolved itself into the opinion which the test pilot formed, a purely qualitative conclusion not based on exact scientific data and arrived at by one not trained in the art of exact observation and operating under conditions which did not insure satisfactory precision. It is only natural for an aviator flying a new, unfamiliar, and untested plane to be more concerned with his own safety than with the precise extent to which the plane responds to his maneuvering. All of this created an uncertain, unsatisfactory, and highly unscientific situation. The National Advisory Committee for Aeronautics undertook to remedy it, and the amazing part of it is that while the work is not yet completed, enough has been done to place airplane design and testing on a sound basis and to insure proper precision in the taking of observations.

To accomplish this required the creation of a research organization unlike anything previously in existence, the design of novel and ingenious research methods and instruments, and the carrying out of thousands of tests in the laboratory, on the ground, and in flight.

ORGANIZATION OF AERONAUTICAL RESEARCH BY THE N.A.C.A.

We shall discuss the organization of research first, which is primarily a management problem that differs from the organization of an industrial plant in many ways.

Organization of research is basically unlike the organization of a manufacturing plant and approaches that of a jobbing machine shop in that, instead of production being essentially a repetition

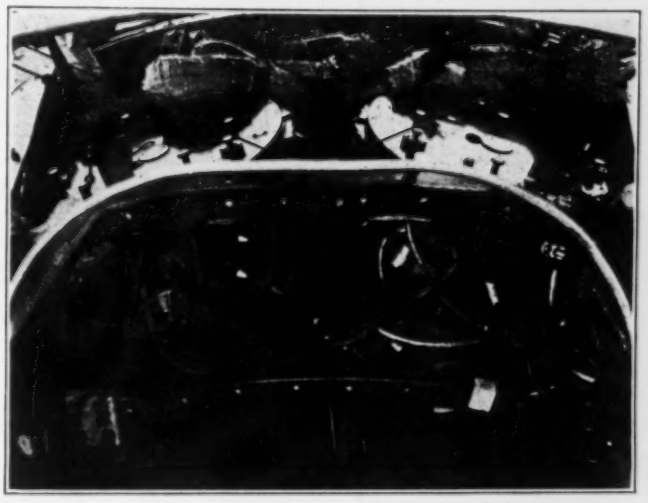

FIG. 6 MULTIPLE RECORDING MANOMETER (FIG. 5) MOUNTED ON COCKPIT

(This shows also the tubes leading to pressure buttons on various parts of the airplane wing by which the pressure at a given spot is communicated to the manometer.)

of a given set of operations, every job presents an individual problem entirely novel in its main aspects and one that has to be handled in its own way.

In the National Advisory Committee as it is organized, problems may arise in several different ways. A problem may be proposed by the Committee itself or by one of its members; it may be suggested by an outsider or an outside organization, perhaps in connection with an invention submitted to the Committee for consideration; or the Committee may be requested by a Government department, such as the Army or Navy or Post Office, to undertake a research.

Each problem as it arises is referred to one of the three main sub-committees of the Committee and this sub-committee determines broadly the extent to which the problem should be investigated and the organization which should handle it, and submits its recommendations to the main committee. It may thus be handled at Langley Field or at the Bureau of Standards, which latter has a standing arrangement with the National Advisory Committee for Aeronautics for this purpose; or it may be referred by special arrangement to an outside organization such as the Massachusetts Institute of Technology, the University of Illinois, the Leland Stanford Jr. University, or the like, this being done when an outside organization has the proper equipment and personnel to handle the given problem.

It should be clearly understood, however, that the sub-committees of the National Advisory Committee for Aeronautics mark out the program for each given investigation only on very broad lines, especially when the work is to be done in the Committee's own laboratory at Langley Field or at the Bureau of Standards.

The research man is preëminently one venturing into unknown fields. Like David of old he may go out to look for lost asses and find a kingdom. Quite often, however, the contrary happens to be the case. In research it is not unusual to find that apparently minor problems to which scarcely any attention has been paid at the beginning of the work rapidly develop into major ones, and it is not unusual also to find that the problem for which the given research was originally undertaken proves on closer consideration to be no problem at all. Because of this a certain elas-

ticity in instructions is imperative, the governing body, such as one of the main sub-committees, keeping in close touch with the work of the laboratories through progress reports and occasionally through personal observation.

When the problem reaches the Langley Field research laboratory it is then considered at a conference of the engineer-in-charge with such heads of divisions as may be interested in it. For example, a given problem may deal with the determination of the aerodynamic properties of a new wing. In the conference with the engineer-in-charge would be the head of the Wind Tunnel Division, the head of the Instrument Section, and possibly the head of the Flight Test Division. At this conference the general problem of how this piece of research should be carried on is considered, as well as the research facilities available and the new instruments or appliances that have to be provided. A tentative time schedule is established and an estimate of the cost of the given investigation drawn up. Such a conference is usually quite informal, no minutes being kept and each member present taking notes as to what his group should do and when it may call upon other groups to assist in the new undertaking. In addition to this brief conferences of all the heads of the technical divisions and sections are held every week, at which progress reports are made as to work in hand so that all can keep track of what is going on. The general organization of the laboratory may be seen from the chart in Fig. 1.

The laboratory is equipped with a small instrument shop capable of doing work of high precision. As far as possible all heavier and rougher machine work is done by outside contract, although facilities therefor are available in the laboratory if the need is urgent. When it is decided to build a new instrument or piece of apparatus, the practice is to carry the design work in the drafting room only to the extent necessary to establish a proper basis for the construction of the first model. No attempt is made to produce a full set of shop drawings, a complete idea of the design often being present only in the brain of the engineer. As the parts are being completed, it takes shape. Sometimes changes have to be made either on parts already produced or by making entirely new parts. In case the new device is an addition to the family of recording or indicating flight-test instruments, it is tested out first in the laboratory and then in flight. If it is found that its operation approximately meets expectations, changes are incorporated and further tests are made until the performance of the apparatus fully satisfies the requirements or its limitations are determined. While this does not at first appear to be a very scientific or logical procedure, experience has demonstrated that it does lead to the production of satisfactory apparatus with the minimum of delay.

When the apparatus has been definitely completed and tested out by use, complete working drawings are made. This is made particularly necessary by the fact that the research laboratory is not a production shop and ordinarily does not build duplicates of the instruments designed in it, since this can usually be done at somewhat less cost by properly equipped outside shops.

In this connection it may be mentioned that methods have been developed by engineers of the laboratory for handling this work in outside shops. It would have been obviously impossible to write complete specifications for each apparatus. Therefore in the several years of its existence, the laboratory has compiled what might be called a "white" list comprising shops that experience has shown can be relied on to do the work satisfactorily, and it is to such shops that the production of instruments from complete drawings prepared at the laboratory is farmed out. This method, while somewhat informal, has been found to be most productive of results.

Research Personnel at Langley Field Laboratory

As regards the personnel of the laboratory, the engineer-in-charge has stated that experience has shown that the best plan is to employ good men directly after they have been graduated from college and before they have been engaged in any production work. While they may be lacking in practical experience, it has been found easy to instill into them the true spirit of research, a matter somewhat more difficult in the case of engineers who have been taught to concentrate on "getting the work out."

Naturally the turnover in the ranks of the researchers is quite high. After the young men have been at the laboratory a few years they find themselves in possession of a considerable amount of valuable engineering experience and training, and to obtain their services commercial organizations offer them pay far greater than the modest salaries with which the Government compensates its scientific men.

In a way this handicaps the work of the laboratory, but no serious objection can be made, partly because of the gratification natural in seeing men leaving the laboratory to occupy responsible positions in the outside world, but especially since in this way the laboratory comes to occupy the position of a school sending out its missionaries into the industry to teach respect for aeronautical research and methods for bettering American aeronautical products. The industry badly needs such a school, and in training the research force of future American aircraft factories the Langley Field laboratory and its allied organizations are performing a valuable service to the cause of national preparedness.

On a visitor to the laboratory this feature produces a strong impression. Aeronautics from the beginning has been a young man's game, and as one passes from one building of the laboratory to another he constantly meets keen young men with the latest information on their respective subjects at their finger tips. And the amazing thing about it all is that these young men with but scanty financial means at their command are achieving results which are rapidly revolutionizing the industry and converting it from one of unadulterated guesswork into an exact science.

Wind-Tunnel Testing

The Wind Tunnel Division has two tunnels, one of conventional design built of wood, and the other of the so-called "high-pressure" type and of radically novel construction.

The art of testing various wing, airplane, and propeller shapes in wind tunnels has been brought within the last twelve years to a high state of perfection and the instruments developed in this time make it possible to measure and record the performance of a model in a wind tunnel with great reliability and precision. The trouble begins when an attempt is made to interpret the data obtained in a wind tunnel in reference to their application to full-scale machines. There is the so-called law of "dynamical similarity" which purposes to express the relation between results obtained on models and the performance of full-scale machines, but the extent to which and the precise way in which this law should be applied is still a matter of considerable uncertainty.

The compressed-air tunnel, Figs. 2, 3 and 4, represents an interesting attempt to apply a novel principle to the testing of model shapes. Briefly and without going into aerodynamic intricacies it may be said that a model of a length, say, of 6 in. in an air stream having an absolute pressure of 5 atmos. behaves in the same manner as a model 30 in. long would behave in air at atmospheric pressure. In other words, an increase in the pressure of the ambient medium in which a model is tested is equivalent to an increase in the size of the model at approximately the same rate as the increase in pressure.

This is a rather novel departure in testing airplane shapes and not enough work of the kind has been done to show its exact value. It is fortunate, however, that at the Langley Field laboratory sufficient equipment is available to obtain precise data as to the behavior of various wing shapes when incorporated in full-size airplanes in flight, and it may be expected that a comparison between data obtained from the normal-pressure tunnel on the one hand and from the compressed-air tunnel on the other, when compared with data obtained from wings of the same shape in actual flight, will throw a vivid light on the still obscure but highly important law of dynamical similarity.

As shown in Fig. 2, the compressed-air wind tunnel known in the laboratory as Wind Tunnel No. 2 is essentially a riveted tank of quite respectable dimensions, 15 ft. in diameter by 36 ft. long, built of steel plate $2^1/_8$ in. thick, which is none too much considering that the apparatus is designed for working with a maximum pressure of 300 lb. per sq. in.

Inside the tunnel is a propeller which circulates the air and creates the necessary air stream; spy windows are provided to observe the instruments, which latter may be controlled from the outside by the observer.

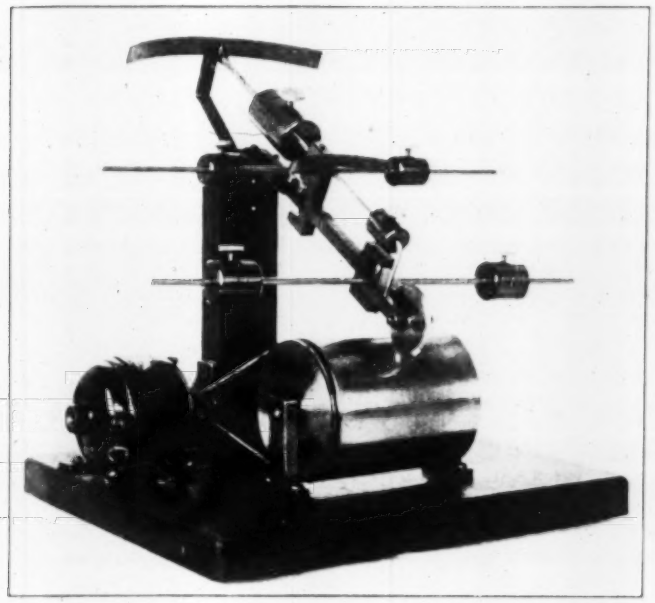

FIG. 7 APPARATUS FOR INDICATING STABILITY CONDITIONS ON AN AIRPLANE

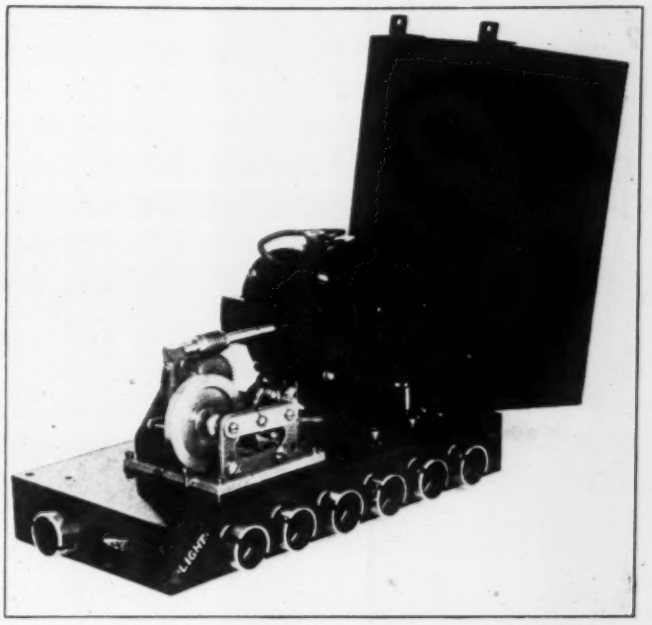

FIG. 8 ELECTRIC CONTACT-MAKING CHRONOMETER, AN INSTRUMENT USED IN COMBINATION WITH OTHER INSTRUMENTS AND ADDING THE TIME ELEMENT TO THE OTHER RECORDS

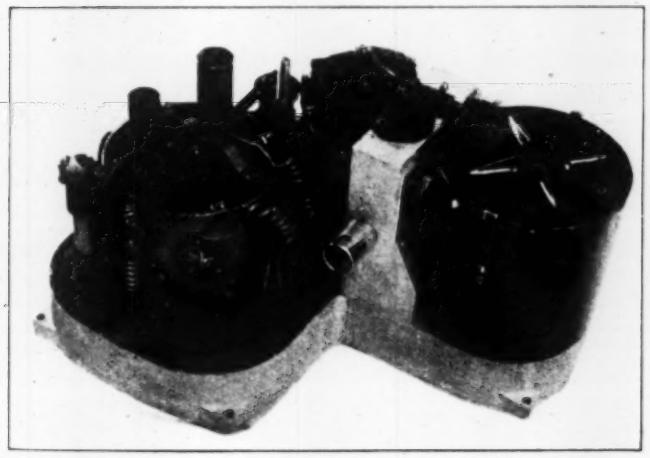

FIG. 9 NEW RECORDING G[illegible]OSCOPE

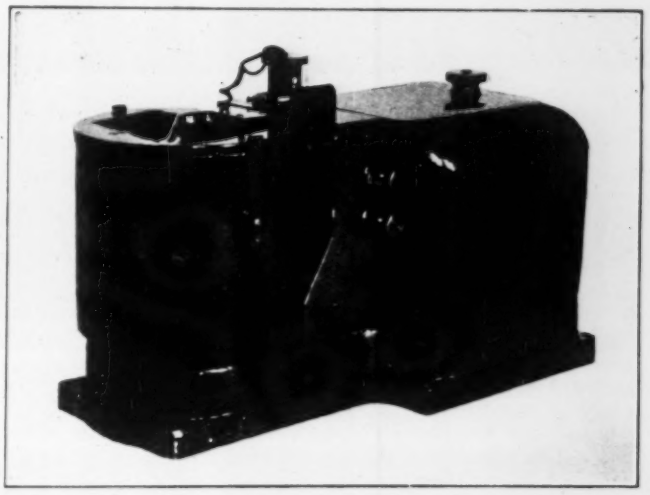

FIG. 10 NEW ACCELEROMETER SHOWING THE RATE OF VARIATION OF SPEED OF AN AIRPLANE

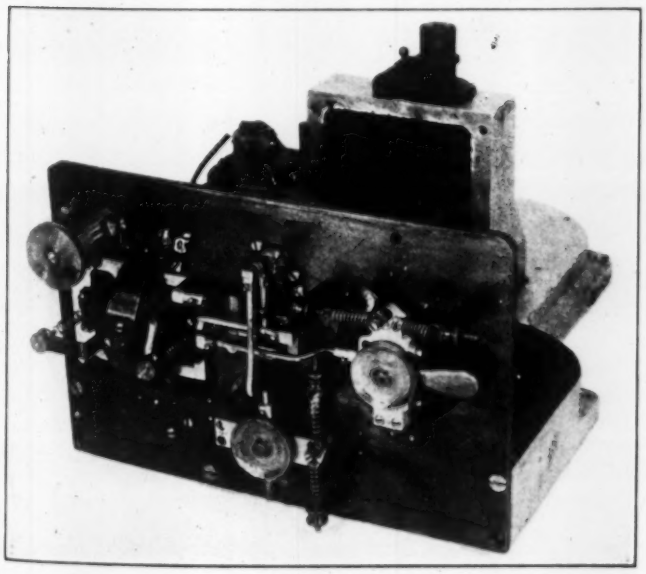

FIG. 11 THREE-COMPONENT GYRO TURN INDICATOR, THE PURPOSE OF WHICH IS TO INFORM THE PILOT OF ANY DEVIATION IN FLIGHT FROM THE STRAIGHT-LINE DIRECTION

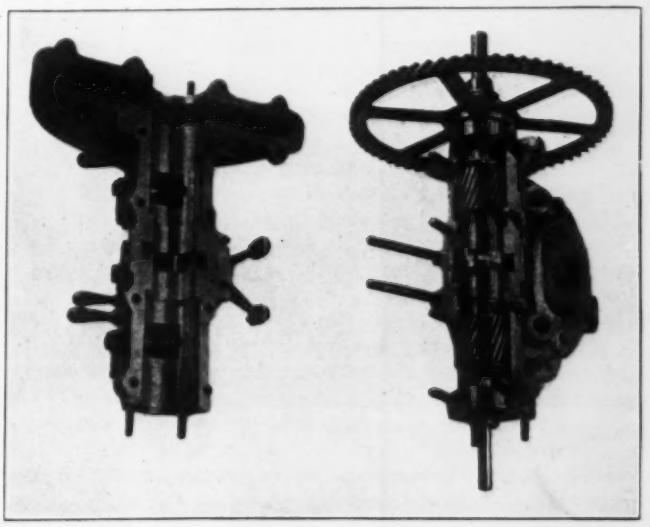

FIG. 12 VALVE-GEAR MECHANISM FOR VARYING VALVE LIFT OF THE UNIVERSAL TEST OIL ENGINE SHOWN IN FIG. 13

Instruments for Determining the Magnitude and Distribution of Stresses in Aircraft

One of the most important problems in the design of either an airplane or a dirigible is the determination of the magnitude and distribution of the stresses in the structure. It is obvious to any engineer that before he can design a piece of machinery he must know what the stresses are in the entire machine and particularly

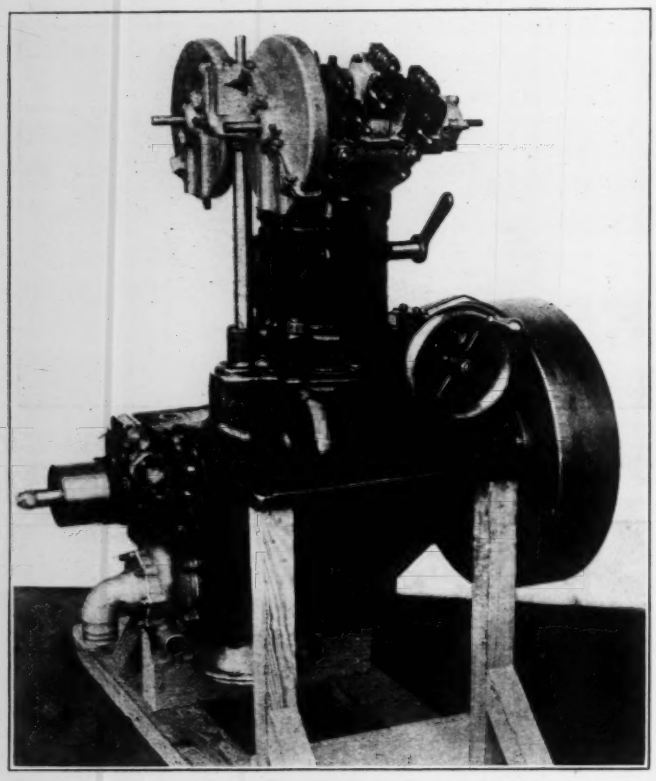

Fig. 13 A Universal Test Oil Engine

(Conditions of operation, such as valve timing, compression pressure, clearance, etc., may be varied while the engine is running.)

the stresses in the parts. This is why we can use a material like cast iron in the foundations, but have to employ steel forgings, possibly special heat-treated alloy steels, in parts rotating at a high speed or subjected to severe vibration. Both airplanes and airships have hitherto been designed in the utter absence of such important data.

While designers for a number of years have known the general nature of the distribution of air pressure over wing surfaces and have been able to apply this knowledge in "sand testing" airplane structures, this mere approximation was found to be untrustworthy when applied to modern high-speed racing and fighting craft, several of which have been the victims of unexpected accidents which were later explained by a more thorough knowledge of the air loads on airplane wings and control surfaces and on airship hulls. The collapse of the Italian-built semi-rigid airship *Roma* in this country and the British-built rigid airship *ZR-2* in England were probably due to lack of adequate load information. The National Advisory Committee for Aeronautics was the first body to undertake a thoroughly scientific investigation of these loads and their distribution, and to carry it through to a successful conclusion.

To do this a new instrument was devised (Figs. 5 and 6) called the multiple manometer, chiefly remarkable for the fact that within a space slightly smaller than a man's silk or stovepipe hat there were crowded thirty diaphragm-type registering manometers. These were connected by small tubing to small brass pressure buttons located at various points of the surfaces of the airplane wing or control surface. The tiny points on the airship in the illustration on the cover of this issue are special "pads" for the same purpose. The pressure at each of these points was transmitted through the rubber tube to the corresponding registering manometer while the aircraft was in actual flight. This permitted recording the variation of distribution of air pressure over the surfaces during various flight maneuvers reliably and without in any appreciable way affecting the behavior of the aircraft itself.

The idea seems to be very simple, but it required an immense amount of thought and engineering design in order to carry it through successfully, and it gave truly amazing results. In the first place, it was found that the distribution of load over the wing of an airplane flying at high speed was decidedly different from what had been anticipated. There have been cases, especially after a rapid dive, where the fabric on the upper side of the wing was actually torn off at the forward edge. There did not seem to be any reasonable explanation for this as the loads were supposed to be of the order of 50 lb. per sq. ft., which was considerably less than the fabric was capable of withstanding.

In the tests of the National Advisory Committee for Aeronautics it was found that the loads reached a maximum of 210 lb. per sq. ft. instead of 50 lb., or were more than 300 per cent greater than hitherto supposed. This means that the forward edge of the wing will have to be reinforced in some way. It will also probably mean that a complete and intelligent redesign of the shape of the wing must be effected to avoid this undersirable localization of the load; and in any event it will mean a more intelligent handling of flight problems themselves.

Another entirely unexpected result of these tests was the discovery of unsuspected extreme load concentration at the wing tips, which explained several instances where the wings had buckled and fliers had been killed. Here the solution of the problem has already been found, namely, altering the wing-tip shape and giving to the wing a negative angle at the rear, a simple matter which

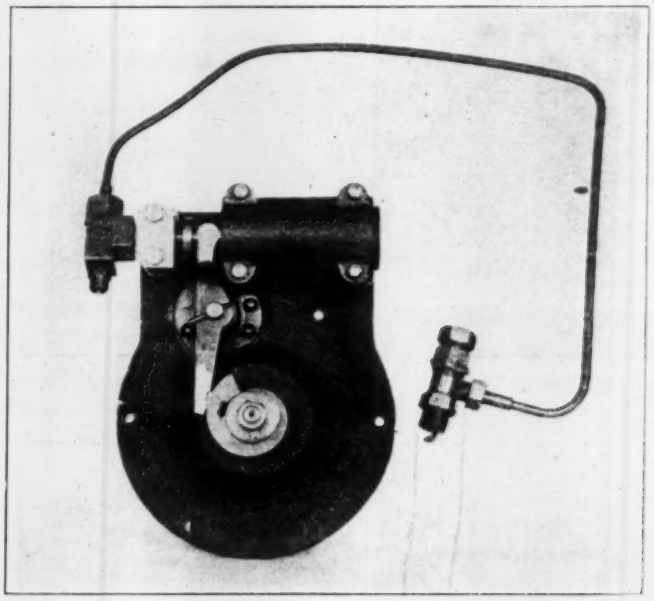

Fig. 14 Fuel-Injection Pump Developed for Use with the Special Single-Cylinder Test Liberty Engine Shown in Fig. 15

will save many valuable lives; and yet it could not have been arrived at without some such methodical and scientific investigation as the Committee and its engineers applied and are applying to the problems of aeronautical design.

While space does not permit going into this matter more fully, the cover illustration shows that the same methods have been employed in the design of airships. Without revealing any military secrets, it may be stated that the results of this investigation have been already taken into careful consideration in the design of the huge Navy dirigible *ZR-1* now under construction at Lakehurst, N. J., and because of this there is reason to hope that it will escape the fate of the *ZR-2* and the *Roma*.

In general, it is the aim of aerodynamical experts of the National Advisory Committee for Aeronautics to place the design of an airplane on the same scientific basis as that which has been employed for a long time in bridge design, where it is possible to know before-

hand the stresses to which not only the entire structure but every one of its members will be subjected. The ability of the materials used to withstand these stresses being known, it becomes possible to specify such factors of safety as will insure the proper functioning of the structure under all but absolutely unforeseeable conditions. This is an undertaking of great difficulty and importance, so difficult, in fact, that no practical attempt at it has been made anywhere outside of this country; and it is a matter regarding which American engineers may feel proud that conclusive results have been obtained within a period of less than three years of work, and with the expenditure of an extremely modest sum of money.

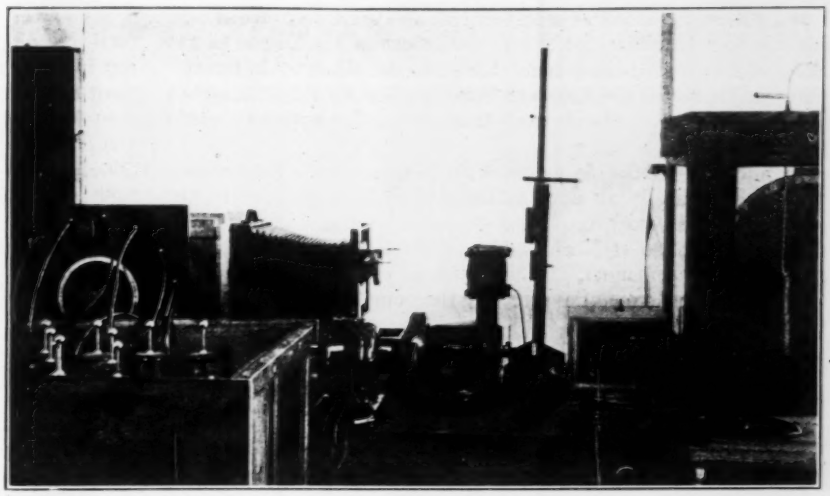

FIG. 16 APPARATUS FOR OBTAINING PHOTOGRAPHS AT A HIGH RATE OF SPEED (OF THE ORDER OF 5000 PER SEC.) TO SHOW CHARACTERISTICS OF FUEL SPRAYS
(This apparatus is used in connection with work of developing a fuel-injection oil engine for aircraft.)

FLIGHT TESTING OF AIRPLANES

"The proof of the pudding is in the eating," but this does not mean that all who eat the pudding will agree as to its qualities. There is presumably about as much variation in the ability of different test pilots to judge of the performance of an airplane, because of the personal element of the flier. Furthermore, there are good grounds for believing that even a reliable test pilot will not always report things as they have actually occurred, no matter how honestly he may try.

In any event, impressions of a test pilot, and that is practically what a report of the ordinary test flight amounts to, are too indeterminate to make a comparison possible. As a result of this there has been in the past no reliable way of determining the qualities of an airplane in flight, in particular its controllability and maneuverability.

To solve this problem the National Advisory Committee has developed a series of instruments which give exact information as to what the pilot does in flight at any given time, and show beyond cavil just what happens as a result of a given action of the pilot.

The most interesting of these instruments are those designed to record the actions of the pilot in controlling the airplane. Many of the controlling operations of the pilot are very nearly automatic in about the same way as are those of an expert automobile driver threading his way through congested traffic. They consist of a series of slight movements of the steering wheel, light pressure on the accelerator, and possibly a shift of the brake, all of these being instantaneous reflexes to the state of traffic ahead as viewed at each succeeding moment by the driver. The airplane pilot "feels" his machine, and by slight movements of the control elements keeps it on the desired course. Not every pilot controls his machine in the same way, since not all have the same quickness of reflex or the same "feel" of the machine.

A new instrument has been developed called a control position recorder, by means of which every movement of the "joystick" is recorded and timed. This is not all, however, because in addition to recording what has actually been done, it is necessary, in order to judge of the controllability of an airplane, to know how much of an effort a pilot has had to exert to obtain a given result. This again can now be recorded and timed by means of a control force recorder, the two instruments together giving a complete record of what the pilot has done.

The next problem was to find out to what extent the airplane responded to the control operations of the pilot—whether it made the turns, dives, "zooms," etc., demanded of it, and how rapidly it did so. For this purpose an interesting series of instruments were developed. These are shown in Figs. 7 to 11, and the stability of an airplane, its ability to take turns, to accelerate, etc., is, or rather may be, recorded synchronously with the "position" and "force" records of the control apparatus. A comparison of the two records will show exactly and independently of any personal element of the test pilot just what had to be done to keep the airplane on its prescribed course and what its ability was to stay on that course and to respond to such changes as might be demanded of it. In this way it now becomes possible to obtain what may be called an index number of the controllability and maneuverability of an airplane, which enables one to compare two given machines fairly, reliably, and intelligently—something which has never been done before and cannot be done without a set of instruments of the type developed by the Committee.

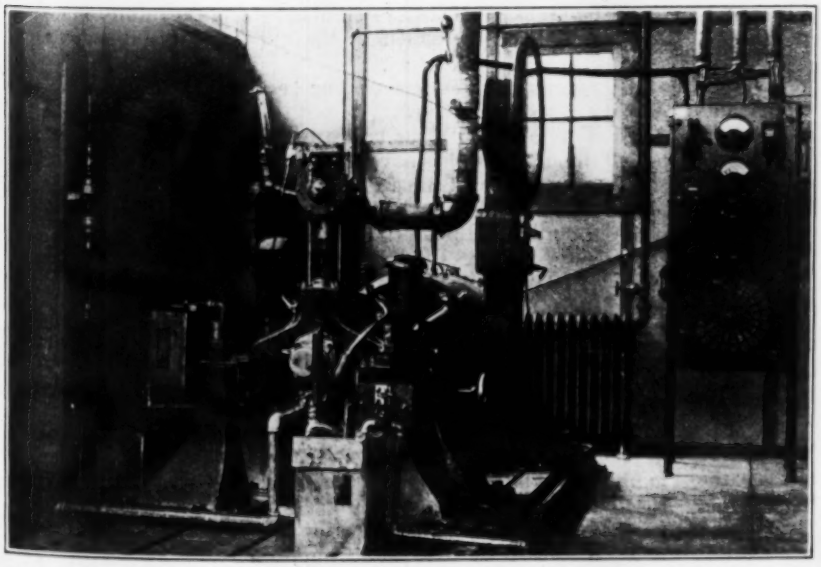

FIG. 15 GENERAL SET-UP FOR TESTING A LIBERTY SINGLE-CYLINDER SPECIAL UNIT WHEN OPERATING ON FUEL INJECTION AND AUTOGINITION

TEST AIRPLANES

In this connection it may be mentioned that at the Langley Field research laboratory the Committee maintains a rather interesting assortment of airplanes. There are thirteen machines of ten different types ranging from single-seat Bee Line racers capable of making better than 180 m.p.h. to a huge torpedo carrier that looks like an aerial truck and carries about as heavy loads. The Committee has the services of two pilots, and it is the belief of the engineering personnel that work such as is done by the laboratory in the air should be performed by test pilots specially selected and trained for it rather than by ordinary flight pilots. The reason for this is that test pilots are more inclined to obey strict instructions as to what they should do than are ordinary flight pilots. Of course, when it is necessary to have extra machines in the air, arrangements are made to borrow the necessary personnel and equipment from either the Army or the Navy.

With thirteen machines in the hangar and extremely elementary facilities for handling the work, the laboratory manages to get along with two pilots and six mechanics in the hangar. In the two years that heavy flying has been done the laboratory has a record of close to 500 hr. in the air in all kinds of weather without a single smashup.

In addition to the flying work in heavier-than-air machines, which is practically all done at Langley Field, a certain amount of experimental work on lighter-than-air machines is performed at the Navy Base at Norfolk, Va. This is being done with the regular Navy personnel, the engineers of the National Advisory Committee for Aeronautics directing the actual tests and acting as observers.

Oil-Engine Design

One of the many problems that are interesting today every aeronautical power-plant engineer is that of the design of an oil engine for aircraft. The National Advisory Committee for Aeronautics is devoting a good deal of attention to this problem at its laboratory at Langley Field and is going about it in a way that is certain to result in greatly broadening our knowledge of medium-compression engines. This work is being carried forward in three directions. In the first place, tests are made on a dynamometer outfit with a single-cylinder Liberty engine, and while some interesting results have been obtained, a great handicap exists in the fact that this engine was not initially designed as an oil engine and, therefore, no matter how much it may be tinkered with, it will not give high efficiency as such.

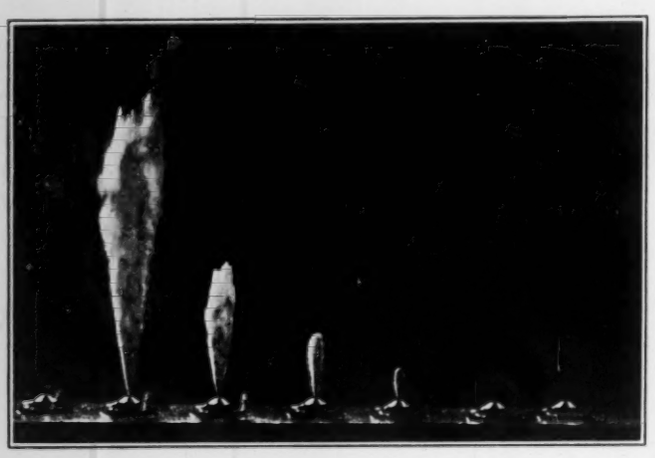

Fig. 17 Instantaneous Photographs of Fuel Sprays

(As noted in the text, these photographs were taken with an earlier type of apparatus and not with that shown in Fig. 16.)

From this point of view a good deal more may be expected from the unusual single-cylinder "universal" oil engine shown in Fig. 13. One of the features of this engine is that the compression ratio can be changed while the engine is running, as can also the timing and lift of both inlet and exhaust valves, as well as the fuel-injection characteristics.

This experimental work on actual engines is of course of great value, but after all so many variables enter into the operation of an engine that it is practically impossible to determine completely the influence of each one of them, and yet without taking them into consideration it is impossible to perfect a truly scientific design.

Because of this the laboratory undertook what appears to be a highly original research, namely, that of learning the behavior of various jets as affected by each of the several variables that enter into the determination of the character of the spray. Among these may be mentioned the shape and size of the nozzle, the pressure of the fuel, the temperature and viscosity of the fuel, the temperature and pressure of the gaseous medium into which the spray is injected, turbulence, etc.

The only practical way to investigate the various kinds of sprays appears to be by securing a photographic record of their gradual development. An apparatus (Fig. 16) was therefore built which made it possible to take photographs at the rate of 1350 per sec. Some of these photographs are shown in Fig. 17. Illumination for these photographs was provided by means of electric sparks, but in the initial installation the illumination proved to be insufficient to give the desired clarity of the pictorial image. The apparatus was therefore completely redesigned and is now practically completed. With it photographs may be secured at the rate of 5000 per sec., and the illumination has been increased so that it is now about tenfold what it was initially. From eight to twelve photographs may be taken during the period a jet is developing from its beginning to full size. It is easy to see what a light will be thrown on the process of jet formation by an accumulation of such photographs.

This, together with other developments at the research laboratory, may be taken as an indication of a determined tendency on the part of the Committee to organize its research so as to obtain data that will be as free as possible from errors introduced by the personality of the experimenter. In the case of jets this is done by photography, and in flight tests by means of the several recording instruments which tell exactly what the pilot and the airplane did. The behavior of the airplane itself is written down by kymograph, gyro turn indicator, single- or three-component accelerometers, gyro position recorder, angle-of-attack recorder, etc. To know by record and by measure is a good rule to follow, especially in a science as young and unorganized as aeronautics.

International Air Congress

THE following are brief extracts from two timely and informing addresses delivered before the International Air Congress held in June of this year in London on invitation of the British Government.

The Duke of Sutherland, who acted as Chairman of the Main Committee of the Congress, in delivering his inaugural address, said that the present time was full of great possibilities in the realm of aeronautics. We were on the eve of far-reaching advances in aviation, which might within the next decade or two bring about a partial or complete readjustment of our manner of living. To achieve the desired objects it was, however, essential that the results of research work and the experience derived from the Congress should be properly applied by means of the continued support of governments, and by the business initiative, and patriotism, of private citizens and companies of wealth and influence. The day had gone by when we could leave these things to develop themselves and work out their own salvation. The stakes were too great for us to stand negligently by, while the world's greatest secrets were almost within our grasp. The development of civil and commercial aviation between all countries on a scale hitherto unrealized and the evolution of a popular, cheap light airplane for the public use were both essential factors for the future, and were undoubtedly the forerunners of the world's entry into an aerial age.

J. D. North, in his address on The Technical Development of the Aeroplane, spoke as follows:

"Mechanical flight in the brief twenty years of its existence has passed through four phases, each of an approximately equal period, and which are defined sufficiently clearly to be marked by the observer. There are indications that we are now entering on a fifth phase in the art and practice of aviation, the trend of which forms a legitimate field for speculation.

"Let us take stock of our technical assets. We have a large amount of incompleted work which requires sifting and developing to its proper conclusion. We cannot expect to develop the aeroplane on the heroic lines, the achievement-at-any-price methods, which were proper to the war period. Probably we shall be compelled to concern ourselves mostly with small matters out of the multitude of which great things may come. First, there is the development of the aeroplane from the economic standpoint, the improvement of the ratio of the useful load to the gross weight, and the improvement of fineness whereby for given horsepower this gross weight may be given a better performance. These may be attacked either by systematic improvement of detail or more speculatively by radical changes in design." (*The Engineer*, June 29 and July 6, 1923, p. 682, and p. 5.)

The Port of Montreal

Factors Contributing to Its Development—The River St. Lawrence Ship Channel—Mechanical Handling in Montreal Harbor—Electrification of the Harbor Terminals—Floating Drydocks, Standard Piers, Etc.

By FREDERICK W. COWIE,[1] MONTREAL, QUEBEC

THE PORT OF MONTREAL is essentially a national port. It has been developed upon a national principle, namely, that of coöperating with production in its completest sense for marketing, for warehousing, for collecting, for manufacturing, and for shipping—the principle of a truly modern port.

The total land area of Canada is 3,600,000 square miles; the density of population is less than 2¼ per square mile as compared, for instance, with 30 per square mile in the United States. This vast area, the tremendous distances, and the distribution of the sparse population make the problem of transportation one of vital importance. Canada, with four times the present population, may produce, for export, one billion bushels of the finest wheat in the world.

The fundamental difficulties in the way of production and marketing in Canada are population, climate, and distance. From the center of production in the Canadian Northwest, in the vicinity of Moose Jaw, or Saskatoon, the transportation distance, by rail and water, to Montreal is over two thousand miles. Further, there is also the desire on the part of the farmer to market his products before the winter sets in, when the Great Lakes and St. Lawrence routes are closed. The transportation problem, therefore, is a serious one, and one of the factors in connection with that problem is the port terminal.

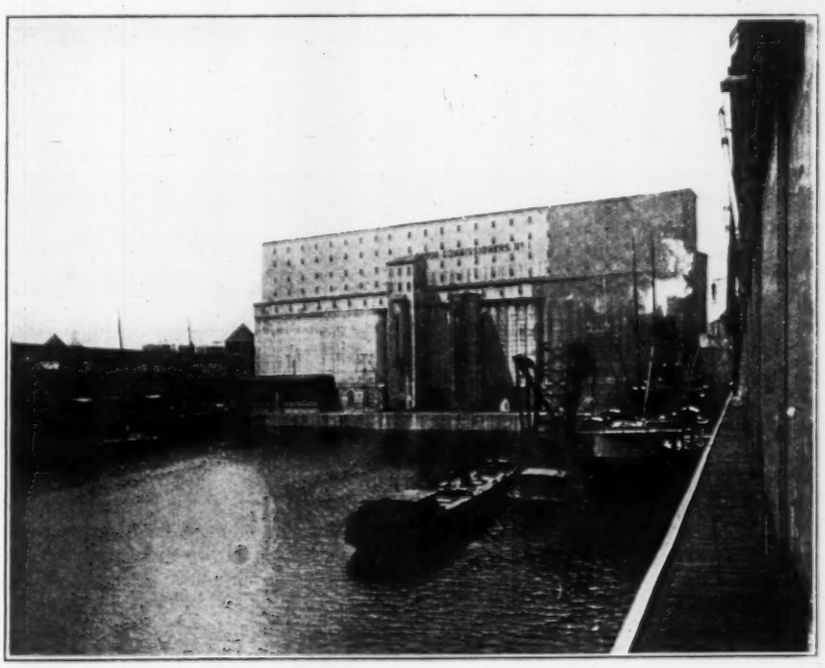

FIG. 1 HARBOR COMMISSIONERS' GRAIN ELEVATOR NO. 1
(Storage capacity, 4,000,000 bushels.)

The development by Canada of navigation on the St. Lawrence, reaching a thousand miles into the interior of the continent; the development of the port of Montreal; and the improved canal navigation between Montreal and the head of the lakes, have been recognized as national necessities and have been promptly carried out to the credit of, and by the credit of, Canada. For a young country with such a small population and limited financial resources, the record is respectfully submitted as being a most excellent one. Not long ago a writer in *Collier's Weekly* summed up matters as follows:

> Within the past decade Canadian enterprise has been building at Montreal one of the most modern and efficient harbors in all the world. Yet the harbor of Montreal is a thousand miles from the sea, and for five months of the year is closed by ice. It has always struck us that the development of the port of Montreal is one of the most daring and sportsmanlike pieces of commercial enterprise that ever has come before our eyes.

[1] Consulting engineer, Harbor Commissioners of Montreal. Mem. Eng. Inst. of Canada.

Contributed by the Materials Handling Division and presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. All papers are subject to revision.

FACTORS CONTRIBUTING TO THE DEVELOPMENT OF THE HARBOR OF MONTREAL

One hundred years ago the city of Montreal had a population of less than 20,000. Quebec was the great Canadian St. Lawrence seaport, and the depth of water in the channel to Montreal was, during the low-water season, only 11 ft. The total ocean freights by ship, to and from Montreal, one hundred years ago could have been carried in one of the several modern ocean steamships which may be seen in Montreal today.

There were then no railroads, and no canals. As the brig of 250 tons represented ocean navigation in Montreal, so the batteau, a flat-bottomed boat, pointed bow and stern, 35 to 40 ft. long, the usual freight being from four to five tons, represented the entire system of transportation to a rapidly developing Ontario, then called Upper Canada or Canada West, as well as to a large section of the United States bordering on the Great Lakes.

In the meantime, while the two provinces, Upper and Lower Canada, could not agree upon financial arrangements, the enterprising citizens of the United States discovered that remarkable pass, the Mohawk Valley, through the Alleghenies, and built their own "St. Lawrence" from Buffalo to the Hudson River, opening it in 1825, one year before Canada opened her first Lachine Canal.

The first Lachine Canal was opened in 1826. Its locks of masonry construction, remarkable at that time, were 6½ ft. wide, and had a depth over the sills of 4½ ft. They were specially constructed for navigation by Durham boats, vessels of 20 to 30 tons. In the meantime Montreal became the point of transfer between ocean navigation and inland transportation, and has retained that position now for one hundred years.

The first harbor commission having in view the improvement and development of the port of Montreal was established in 1830. Montreal at that time had just emerged from being a walled town, and the only port accommodation consisted of the beach extending from the river wall to the water. There were originally five gates from the river to the town, but with the introduction of the river steamer in 1812 from Quebec, and the necessity of more economy in discharging the brigs of that day, wharves were required.

The new harbor commissioners having before them only a sketch plan, decided with wisdom upon obtaining the advice of that eminent civil and mechanical engineer, Peter Flemming, of Albany, N. Y., who had just achieved fame by the successful completion of the locks of the Erie Canal.

Peter Flemming's first report outlined the difficulties, and suggested wharf structures estimated to cost £39,000. He recommended rock quay walls, and his estimate was based upon this type

of structure. Another engineer, whose name has not lived in history, suggested a timber-piling type of structure, and as this was found to save £10,000 it was adopted. Unfortunately, however, when the spring ice shoves swept down upon this timber structure, the inevitable happened.

THE RIVER ST. LAWRENCE SHIP CHANNEL

It was the genius of the mechanical engineer that made possible that great achievement, the River St. Lawrence ship channel from Montreal to the sea.

The first dredge was built in Montreal in 1838, the machinery having been brought from Scotland. From 1840 to 1844 various preliminary works—experimental and otherwise—were carried out, and it was only in 1840 that actual progress was commenced. The author was first identified with this great work in 1886 when it was considered a wonderful and successful enterprise.

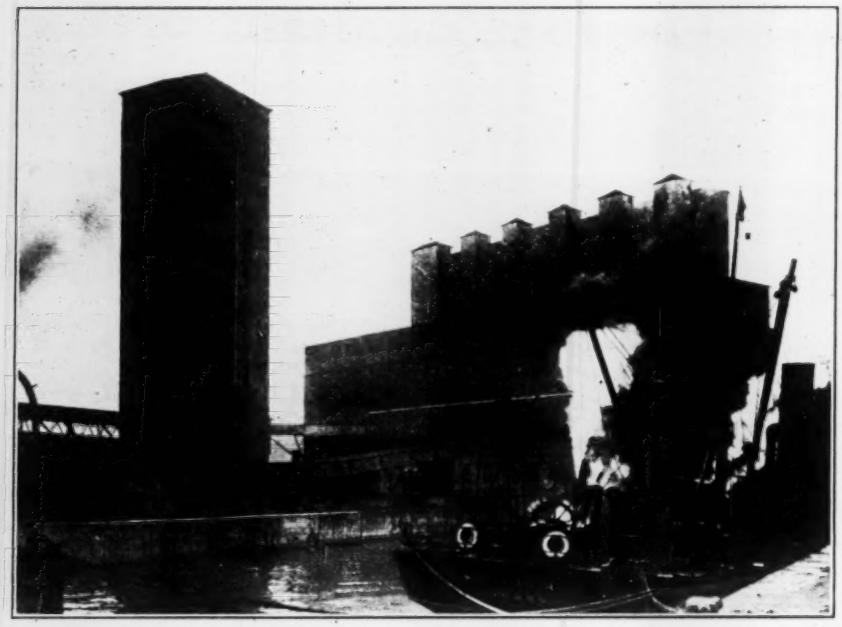

FIG. 2 HARBOR COMMISSIONERS' GRAIN ELEVATOR NO. 2
(Storage capacity, 2,622,000 bushels.)

Two types of dredge were then in use, the elevator dredge and the dipper dredge. It was soon apparent that the latter, though effective, could not coördinate with continuous navigation, and the elevator dredge, floating and held in position by "crab" moorings so that it could quickly haul itself out of the way of passing ships, was adopted.

From Montreal to Murray Bay the total distance by river is 220 miles. In this distance dredging for deepening the natural channel has been required over a distance of more than 70 miles.

Fortunately, owing to the settling basins, the Great Lakes, there is practically no sediment in St. Lawrence water, so that the dredged channel once completed remains permanent. The material varies from a soft blue clay of the consistency of a cream cheese to hard shale rock, almost as hard as ledge limestone. The quantity of material dredged has nearly reached the enormous total of 100,000,000 cu. yd.

It was at Montreal that the elevator dredge was first adapted to dredge shale rock; immense cast-steel buckets with forged special steel teeth, operated by the necessarily powerful machinery, were successfully designed to dredge this hard rock at a depth of 48 ft. in a strong current; and to carry on at a rate of 2500 cu. yd. per day, working day and night; at a cost of 40 to 50 cents per cu. yd.

Immense boulders covering the bed of the river, many of them weighing 50 tons, had to be lifted and removed; all of which was successfully accomplished without blasting.

In Lake St. Peter, where the depth had been originally 11 ft., 18 miles of solid dredging was required. For this work several types of dredges were designed. The late Sir John Kennedy, a mechanical genius, improved the ladder dredges to such an extent that one dredge vessel was capable of dredging and having removed by scows 6000 cu. yd. per day at a cost of 3 cents per cu. yd.

When the project for widening and deepening the channel was undertaken in 1900 under the direction of the author, it was evident that a new departure was required for speed as well as economy. The suction dredge was investigated, but it was found quite impracticable to pump the sticky blue clay of Lake St. Peter by the suction principle. Mr. A. W. Robinson, Mem. A.S.M.E., a mechanical engineer of Montreal was consulted, with the result that the dredge *J. Israel Tarte* was designed, constructed, and put into operation. This dredge, having a rotary cutter and working on the suction plan, was capable of dredging and removing by pipe the mud of Lake St. Peter at the rate of 12,000 to 20,000 cu. yd. per day.

The cross-section of the 8-mile Culebra Cut of the Panama Canal was originally designed at 8000 sq. ft. The cross-section of the St. Lawrence in the three miles of rock cut is 80,000 sq. ft.

THE PORT OF MONTREAL

Montreal Harbor today represents a capital cost of $35,500,000. It is hard to believe that the sixth port in the world, or the second in America, could have been developed, including harbor dredging; wharves, piers and basins; warehouses; grain elevators and equipment; real estate; railways and electrification; permanent sheds; with all plant and equipment, at such a modest price. Port authorities throughout the world may obtain much valuable information by analyzing the principles and methods adopted by the Montreal Harbor Commissioners and which have resulted in such an almost unparalled achievement.

MECHANICAL HANDLING IN MONTREAL HARBOR

It is admitted that only such mechanical handling has been adopted in Montreal Harbor as has been found absolutely necessary and as has been demonstrated to be desirable and economical.

Some years ago, by the direction of the Harbor Commissioners of Montreal, an exhaustive study was made of harbor freight-handling devices by several eminent engineers. These men unanimously agreed that it would be unwise to equip the Montreal docks at that time with any general system of freight-handling devices, except for special freights. The "forest" of cranes which is in evidence in many European ports is therefore not seen in Montreal Harbor. The decision regarding mechanical handling was greatly modified by the recommendations of the author that equal or better economical results could be obtained in the harbor by special correlation between the railways and the docks, the concentration and use to full capacity of facilities, and the extension of the grain-elevator system of delivery of grain to all berths in the central harbor.

Electric hoists were designed, for the first time, to make equally valuable the upper as well as the lower stories of the transit sheds. This design, so very successful, was adopted when team transporting was the rule. At the present time when motor-truck transport is feasible on an 8 per cent grade, there is room for difference of opinion. Practically the whole of the Montreal Harbor system of transit sheds, having a total floor area of 60 acres, is specially well adapted for the use of the storage-battery truck and trailer, and for the new system becoming so general in American ports, namely, the supporting warehouse.

For general cargo, therefore, as may be seen by actual demonstration, Montreal Harbor is sufficiently equipped, in coördination with the splendid freight equipment of the ships, for speedily, economically, and with great satisfaction to all concerned, turning around ships and their cargoes.

Special Freight Handling. While there is satisfactory equipment for the handling of coal in the harbor, Montreal is not an outstanding coal port.

The handling of live cattle is conducted with great rapidity and satisfaction from railway cars through the sheds to the gangways

of the ships, without any special equipment and without requiring the ships to move from their berths.

For the storage and handling of flour special facilities have been under consideration, and it is expected that this feature will require similar study and similar accomplishment as exemplified by the design and installation of facilities for the storage and handling of grain.

The Storage and Mechanical Handling of Grain. In America the areas of export production are at a great distance from the seaboard. Grain has to be transported over great distances and handled many times as compared with the producing areas in competing countries. Moreover it is difficult to realize the magnitude of the quantities of grain produced in America. In North America the production of grain annually is in excess of six billion bushels. At least five hundred million bushels are exported, and, let us say, three hundred million more are shipped to some local market, the remainder—two and a half billion bushels—being consumed on the farm.

In America, as a rule, export grain is handled at a country elevator, at the head of the lakes, at a lower lake port, at an ocean port, at a port in Europe, and at the final milling point. The cost of this handling for the export business may be estimated at 8 cents per bushel and amounts to $40,000,000 annually. The three billion bushels of local grain are handled at least twice, at an estimated cost of, say, 2 cents per bushel; a further amount of $60,000,000 annually. That is, the cost of handling the grain grown in America amounts to something like $100,000,000 annually. What a prize if the cost could be decreased 25 per cent, or even 10 per cent!

The port of Montreal is one of important handling ports for export grain in America and last year handled over 155 million bushels. Without the grain business and profits on handling, Montreal would not be the second port in America.

When it is considered that on the opening of the Canadian Pacific Railway in the West in 1886 there were no facilities and no organization of any kind for the handling of grain, one is profoundly impressed with the successful mechanical development which has resulted in the handling of the present production with one-sixth of the Canadian Northwest agriculturally developed; and with the requirements of the future, when five-sixths will be sending their streams of export to the markets of the world.

It may be asked, "Is there anything left in the way of possible improvements?" But when it is considered that grain may be received, weighed, stored, reweighed, and delivered to a ship at her berth half a mile from the elevator at about 50 cents a ton, why not rest satisfied?

During the war, when labor was so scarce and shipments required to be urgent, it was found almost impossible to unload promptly the railway cars containing grain into the elevators. The author accordingly undertook an investigation into the possibility of the mechanical unloading or dumping of cars. This investigation was later continued by the John S. Metcalfe, Co., Ltd., of Montreal and Chicago, who finally succeeded in designing a grain-car dumper which has solved the problems of labor, time, and cost in a most satisfactory manner.

When it is considered that the old method of unloading grain cars by shoveling required from four to five men for half an hour, while, with the new dumper, it takes a similar gang only six minutes, its value will be appreciated. A feature of the car is that it may be installed in a separate building, thus greatly minimizing the danger from dust explosions.

There remain, however, serious problems requiring solution, such as the trimming and shoveling of grain in vessels in America, and particularly in the European ports.

The Mechanical Handling of Flour. As wheat unmanufactured is exported in great quantities, so manufactured wheat or flour is now becoming a very important item of American commerce. Who can solve the problem of a "container" more rapidly transportable and economical of space than the barrel and less wasteful and better than the sack, and thus make flour shipment compete with that of bulk wheat?

The Cold-Storage Warehouse. Last year there was opened for business in the harbor of Montreal a cold-storage warehouse, which was built to aid the producer in the preservation and marketing of his products and to lengthen the season for the consumer for many articles of daily consumption. This first example of this phase of harbor development is only a beginning, and modern ports are in many cases now considering this type of harbor enterprise.

Electrification of the Harbor Terminals

The Montreal Harbor railway terminals consist of surface lines situated between Victoria Bridge and the Imperial Oil Wharf, a distance of 10 miles, and have a total trackage of over sixty miles.

For several years nine standard locomotives have been in operation. Recently, however, it appeared that if the service was to be maintained to its highest efficiency, additional locomotives would be required to maintain a prompt service.

After investigation and study, electrification has been found to be not only economical but more efficient than the use of steam locomotives, especially during the winter months, the price of coal having in recent years advanced 300 per cent as against an increase of only 8 per cent for hydroelectric power. Further, through the Canadian National Railways' electrified terminal the Harbor Commissioners have a marginal harbor railway terminal connecting all railways and all plants on the river front with the harbor docks.

Floating Drydocks

Opposite Maisonneuve a tract of land 30 acres in extent was reclaimed from the harbor and leased to Canadian Vickers, Ltd. A shipbuilding and repairing plant was installed here and the floating dock *Duke of Connaught*, built in England, was towed to the same location from across the ocean. This drydock is capable of accommodating the largest existing vessel of the British Navy and has the following dimensions:

- Length, 600 ft.
- Width, 135 ft.
- Length of side walls, 470 ft. 6 in.
- Height of side walls, 59 ft.
- Draft of vessel for dock, 30 ft.
- Lifting capacity, 25,000 tons

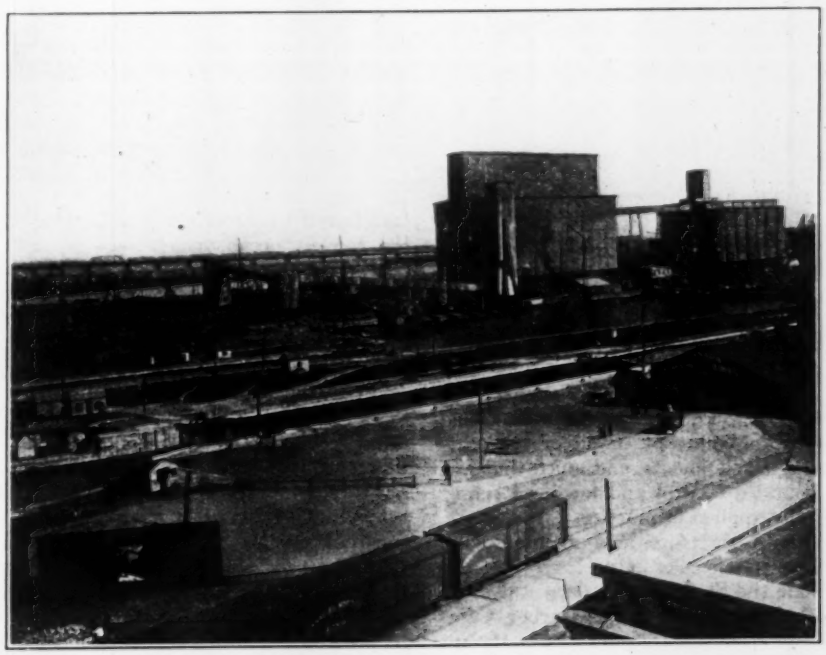

Fig. 3 Grand Trunk Railway Grain Elevator
(Showing in foreground locks at entrance to Lachine Canal; storage capacity, 2,100,000 bushels.)

Standard Piers in Montreal Harbor

A standard pier in Montreal Harbor is 1200 ft. long and 300 ft. wide. The interior filling of the pier is solid, so that the ground-floor or pier cargo weights are not limited.

The pier area is laid out with one standard railway track on the quay front. Closely adjoining this track there

is a two-story transit shed 100 ft. wide and 500 to 600 ft. long, built of steel and concrete and fireproof throughout. The lower floor is elevated to the height of a freight-car platform.

In the pier center, adjoining the shed, there is a 6-ft. trucking platform, two standard railway tracks, and a roadway. For the inner sheds and also for the outer sheds there is a vehicular elevator. These elevators carry two trucks at a time up to the upper-story level, and at each elevator a transverse bridge connects with the two sheds.

The marginal railway required to feed this pier, assuming shunts to be made every six hours, day and night, has been found to necessitate two standing tracks for waiting cars, two through-running tracks, and two other tracks partially for waiting cars and partially for teaming, the length required for each pier being at least 1000 ft. This is in addition to the holding yards at various points in the terminals.

The upper stories of the transit shed are designed to carry a floor weight of 600 lb. per sq. ft. They are used almost entirely for imports, but also to some extent as collecting warehouses for export freights.

Grain is delivered to these berths from overhead conveyors entirely separate from other cargoes. Ships may receive grain from two belts at a time at the rate of 15,000 bushels per hour each, the grain being spouted directly from the belt into the hold under a head, which with goosenecks eliminates to a great extent trimming in the vessel. Outside of the ship there is ample room for lighterage.

The four berths at each of these piers are designed after long experience for American traffic, and are based on each berth being able to unload an average cargo of 5000 to 6000 tons, and load an average of 8000 to 12,000 tons per week. These berths are used to capacity throughout the season of over seven months.

The St. Lawrence Deep Waterway

For many years the organization known as the Harbor Commissioners of Montreal has been recognized generally as a public trust. Important public interests relating to navigation, to the St. Lawrence route, to maritime commerce, as well as to the harbor of Montreal have been entrusted to them, not only for development but for guarding inviolate the rights, obligations, and interests of Canada in the River St. Lawrence district.

The commissioners have declared officially that their policy must be commercial development; their duty, to guard and improve navigation. They submitted for the consideration of the International Joint Commission their opinion that approval of every important project connected with the St. Lawrence should be withheld until a properly developed plan has been prepared, taking in the whole river from Lake Ontario to Montreal, that will fully safeguard for the people of the United States and Canada their heritage in connection with:

1 Navigation
2 Hydroelectric power
3 Regulation and flow.

Why, it may be asked, is the St. Lawrence deep-waterway project more acutely before the public today than it was ten years ago? Ten years ago steam coal was available in Ontario and Quebec at $3 per ton, and the supply was ample. Today the price is two and a half or even three times higher and the supply unreliable. Ten years ago the price of transportation of a bushel of wheat from the farm to the United Kingdom market was 15 cents. Today it is double that.

Before the war Canada was not the equal of other countries as regarded engineering and industrial works and variety of industrial output. Today, however, she can build any or all of the parts needed in hydraulic and electric developments, and much that was not known ten years ago about ice control and low-head power has been learned and successfully applied in practice.

What equal project in the world, therefore, now offers an equal return to man from the generous resources of nature?

For navigation purposes alone the St. Lawrence deep waterway may be admitted as of doubtful economy. The Harbor Commissioners of Montreal, however, representing not merely the interests of Montreal but of all Canada, have taken an eminently fair attitude upon this question. In their excellent annual reports they have stated that they do not believe that ocean vessels, except specials, are either fitted for inland navigation or can compete with the Great Lakes type of vessel, including a transfer at Montreal.

They would welcome and have reserved harbor accommodation for the 10,000-ton lake vessel, but they specifically state that, in their view, public money at the present time, if available, will yield better returns if applied to improving proper port terminals.

Navigation improvements and the development of hydroelectric power may come hand in hand. The latter may pay for the former. But before such a scheme may be considered, it should have, and it is worthy of, the most profound consideration and the most careful investigation.

A Montreal Bridge Project

Seventy years ago, when railroad transport had proved its success, a bridge was projected and later built to carry railway trains across the St. Lawrence. Today it is a question of the requirements of a bridge for motor transport.

In 1919 the limits of Montreal Harbor, placed by the Canadian Government under the jurisdiction, control, and management of the Montreal Harbor Commissioners, were extended to include the beach and bank of the south shore of the River St. Lawrence to high water mark, and to include both sides of the river down as far as Bout de l'Ile. The object of this enlargement was the coordination of all units of harbor development into one scheme.

A Montreal bridge scheme, and there are several, with its possibilities for industrial developments, its harbor connections, its possible connection with the island and the south shore and its location so near the center of the City of Montreal, offers attractive possibilities. The Harbor Commissioners' construction work and administration have received the approval of the public, and taking the point of view of navigation and other administrative requirements, it is believed that they could operate this bridge in the public interest.

Discussion

IN THE DISCUSSION which followed the presentation of the paper the author, replying to a question asked by W. S. Jacobs[1] regarding the unsuitability of ocean vessels for inland-waterway and lake transportation, said that ocean ships were built at very great cost, with very great strength, and with special features for safety. The result was that they had very small rudders and in going into ports, docks, locks and narrow channels, tugs were invariably required. On the other hand, the lake vessel was built very cheaply, with small engine power, a flat bottom, and no keel, but with a tremendously large rudder. The result was that it could go into the Chicago River, the Buffalo River, or any lock in the country without a tug. The cost of construction and operation of the ocean vessel was so high as compared with the lake ship that it was considered that the lake ship could handle the bulk type of cargo that originated in the territory between the head of the lakes and Montreal or some other port where it would be transferred to the ocean vessel, cheaper than if it was carried all the way by ocean vessel.

In reply to a question asked by Augustus Smith[2] as to whether the port charges for the wharf service and for elevator service were sufficient to defray the interest charges and operating charges of the magnificent structures he had described, or whether any portion of such expenses had to be borne by taxation, the author said that the Harbor Commission of Montreal had been in existence for almost one hundred years and had never failed to meet all interest charges and all cost of operation, and that usually they had a tidy surplus. The Commission could always get their projects put through, in spite of the financial situation of Canada, the reason being that Montreal Harbor paid so well and had been found so essential to the requirements of production and industry. In 1906, the year after he had been appointed chief engineer of the Commission, the total gross revenue was less than $450,000 and the total debt almost $14,000,000, nearly half of what it was now. At present the gross revenue was $3,500,000.

[1] Treas., Walton Co., Hartford, Conn. Mem. A.S.M.E.
[2] Pres., Bergen Point Iron Wks., Bayonne, N. J. Mem. A.S.M.E.

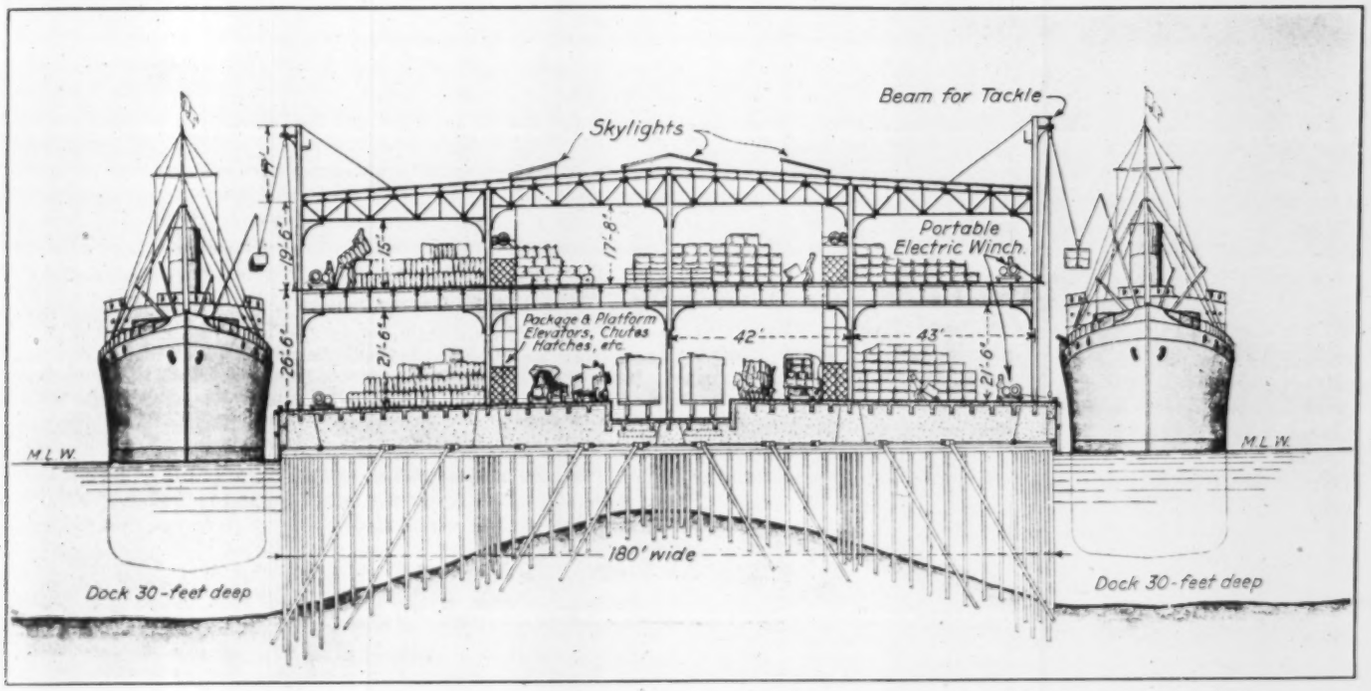

FIG. 1 TYPICAL CROSS-SECTION OF MUNICIPAL PIERS NOS. 38 AND 40, SOUTH WHARVES, PHILADELPHIA

Material-Handling Problems in Pier Design

A Review of the Proceedings of Several Material-Handling Symposiums Held by The A.S.M.E. To Discuss Material-Handling in Its Relation to Port Development

BY CARROLL R. THOMPSON,[1] PHILADELPHIA, PA.

TWO very important factors influencing the plans and policy of improvement and development of our ports which seem to preclude the possibility of substantial standardization of harbor facilities, are

1 The control and operation of the port facilities, and

2 The local conditions of the port,

both of which have a direct bearing upon the character and amount of freight-handling equipment that are justifiable on the pier or wharf.

No material-handling problem is more complex than that of the transferring of freight between land and water carriers at the pier. It is also one that requires diverse consideration of every element involved in the functions of a port, and as these transfer operations center at the pier, the importance of its proper design, layout, and equipment cannot be overstressed.

CONTROL AND OPERATION

In some of our ports where the port administration body owns and operates the facilities there is a greater tendency to experiment with and develop equipment than where the freight movement is entirely in the hands of the pier operators. There is no hesitancy in equipping the facilities with labor-saving devices. The cargo-handling problem is under the direct control of the harbor commission. Accounts, cost data, efficiency records, and maintenance are under constant observation. Inefficiencies can be immediately corrected, whether they be due to faulty equipment or to lack of proper coördination.

At most of our older ports, railroad and private ownership and operation of facilities is more extensive than public ownership, and the handling of freight through the terminals is generally done by shipping companies or stevedoring organizations. The publicly owned facilities are usually leased to private concerns and the *direct* control of freight handling is therefore not under the supervision of the port authority, which would naturally hesitate to equip its facilities with many forms of cargo-handling devices of doubtful efficiency, believing the installations, particularly equipment of the portable type, to be a matter for the operating companies. A harbor authority cannot afford to invest money in freight-handling machinery that may not be used—unless as a means of advertising the port to attract new business. Then again, this policy of port administration brings up the question of responsibility for the maintenance of the publicly owned equipment—which is subject to more or less abuse. Pier operators in their eagerness to turn around a ship in the least possible time often resort to "emergency" repairs in order to speedily overcome a breakdown and put the apparatus in operation while ship loading is under way; and these so-called "emergency" repairs are frequently made by unskilled mechanics who have a very limited knowledge of the construction and design of the apparatus, with the result that more damage is caused and later on serious trouble is encountered and complete overhauling may be necessary. Disputes naturally arise between the tenant and the landlord over the question of responsibility. With public operation this difficulty is eliminated and proper maintenance can be assured.

Some of our port authorities also have functioned very successfully under a policy of constructing pier facilities to attract commerce. In such a policy, however, the specific character of business that may come to the pier cannot be anticipated previous to its construction, and there is the possibility of installing apparatus not adapted to meet such problems of freight handling as may ultimately arise. Under present-day conditions, steamship lines will not wait until pier facilities are built for their particular accommodation but will seek the ports that already have them. A port-authority problem becomes more complicated in attempting to build piers to suit any steamship company's business, and port authorities properly hesitate to expend large sums for extensive

[1] Asst. Director, Department of Wharves, Docks and Ferries, Philadelphia, Pa.

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freight-handling machinery that may remain idle and in the last analysis prove to be a handicap and burden rather than an asset.

LOCAL CONDITIONS

Undoubtedly the most important consideration which enters into the general layout of a port and its freight-handling facilities is the rail and inland-waterway service. One port may be free from the lighterage problem, or comparatively so, while at another it may be practically the only means of interchange between railroad car and steamship. The freight-handling problems of two such ports would therefore differ. In the one case transfer of freight between car and ship is confined almost solely within the pier; in the other a considerable amount of freight would not come in contact with the pier facilities, transfer being made direct between ship and lighter. With the inland waterway service, the port facilities must of necessity be equipped for loading or unloading barges, which do not as a rule carry freight equipment.

Trade in bulk commodities may be the principal commerce of some ports—they may have been developed especially for trade in grain or other bulk cargoes such as coal and ore. The material-handling proposition for such commodities demands that facilities be designed for a particular trade.

Coastwise trade requires a different terminal design from that for foreign trade. The loading or unloading of freight through the side ports of coastwise ships is an entirely different proposition than loading transoceanic ships over the side through deck hatches. Tidal conditions of a port are a very important factor in the design of a pier to be used by "side port" ships; wharf drops or movable gangways are essential for loading operations at all stages of the tide. In coastwise trade a great amount of local freight is brought to the pier by teams and motor trucks—the transportation units that cause the greatest amount of confusion and congestion in pier sheds. The upper story of a two-deck pier shed would be useless for a coastwise terminal operating with side-port ships.

The character of the intercoastal commerce also influences the design. Local deliveries by team and motor truck are very important factors in this trade.

Some ports may be developing for all three of the principal trades—the foreign, coastwise and intercoastal. It is entirely feasible to construct a general cargo pier that will admirably serve any of these trades, although there would be features incorporated in the design of such a combination structure that would prove useless for some of the trades. For example, wharf drops, which are necessary for the coastwise ships, would not be used by transatlantic ships. The upper story of a two-deck pier, which is essential in some ports for the foreign trade, would not be of service in the coastwise trade. A depressed wagonway would be of great advantage on a wide pier for either the coastwise or intercoastal business, while the space it occupies might be used to better advantage for cargo area in some of the foreign trades. Wharf cranes might prove to be valuable equipment for loading export freight but a great disadvantage on a pier used in the coastwise trade owing to the space they would occupy.

It would seem, then, that no one ideal plan of improvement would be feasible for every port and that each port must solve its own problem to satisfactorily meet its own conditions, taking all elements into account.

In speaking of What Constitutes a Modern Port, the late B. F. Cresson, Jr., also considered the effect of local conditions upon the railroad service and pier layouts in the following statements:

> Where railroad cars can be brought direct to the ship's side, piers should generally be built considerably wider than when the service must depend upon lighterage movement between the railroads and ships.
>
> Where there is plenty of undeveloped land it is believed that for economy the initial development should be of the quay type, looking forward to piers if the demands of commerce increase beyond the capacity of the terminal under quay development.

Mr. Cresson also suggested zoning by trade routes as a solution to overcome the disadvantages of equipping piers to accommodate any of the general cargo trades.

BULK CARGOES

Bulk cargo, such as grain, ore, coal, etc., does not present as complicated a problem in handling as the great variety of commodities which form general cargo. Equipment for this class of cargo has been developed to a very high degree of efficiency. Generally shipments are made in full cargo lots and the equipment can be designed exclusively for loading, unloading, or the storage of a uniform product, which greatly simplifies this particular phase of the material-handling problem. Also, such commodities are invariably handled at piers equipped and built especially for the purpose.

MISCELLANEOUS CARGO

The problem of efficiently and economically handling miscellaneous freight or general cargo over piers is the most difficult to satisfactorily solve of any of our port problems; it is most complex and one that demands the utmost flexibility of freight movement. It also requires the introduction of mechanical equipment.

In dealing with the subject of freight-handling machinery on the pier, it must be constantly borne in mind that while the general cargo shed is only a single unit in port-terminal operation, it must be designed to function properly with every other port facility. Coördination of the port's various facilities must be adhered to. Proper conception of the duties of the general cargo pier must not be lost sight of. For quick dispatch of freight between land and water carriers with the many attendent problems in connection with cargo, the wharf should not be permitted to perform ware-

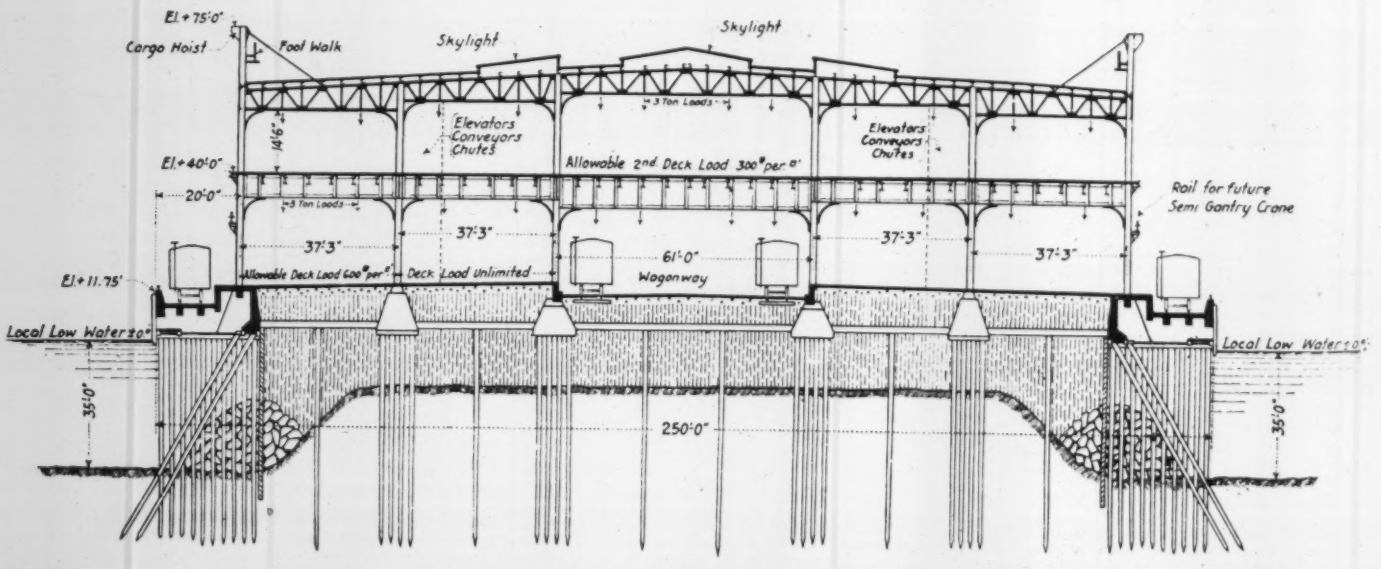


FIG. 2 TYPICAL CROSS-SECTION OF MUNICIPAL PIER NO. 78, SOUTH WHARVES, PHILADELPHIA, SHOWING DEPRESSED APRON TRACKS, DEPRESSED CENTER TRACKS AND WAGONWAY; ALSO PROVISION FOR FUTURE INSTALLATION OF SEMI-GANTRY CRANES

house duties; that is another phase of the general port problem, and while of very great importance to the successful operation of any port, should be treated as a separate unit and coördinated with the pier as well as other facilities.

General cargo comes to the pier shed in many varieties of forms, sizes, and weights, and packed in all sorts of containers, to or from a multitude of consignees and shippers, and over any of the transportation systems entering the port. The first essential purpose of the shed is to provide ample, unobstructed cargo deck space—protected from the elements—for the sorting and assembling of this cargo for delivery to the ship, or to the railroad car or motor truck for removal. General cargo must be spread out on the pier: it must be sorted, classified, checked and weighed, and arranged for proper sequence of loading.

The run in and out of a ship for a few hours may be bagged stuff, the next run of cargo may be boxes or cases that weigh a ton, and then again in the same hold of the ship there may be a class of freight measuring a foot or two in diameter and ten or twelve feet in length, and so on. In loading cargo the various consignments from a great number of shippers must be kept separate, while import cargo must be handled in a specific manner for customs weighing and inspection. This further complicates the problem.

In modern pier operation it is impracticable to tier goods to any great height. Dr. R. S. MacElwee has pointed out that for short-time storage it is not economical to pile above five feet high.

Ample deck area is the first essential for a modern-day pier. In addition to the space required for cargo purposes, space is also needed for railroad tracks—which in a modern port are as necessary to the pier as the berth for the steamship—and considering the importance of freight delivery by motor truck and team, additional width of pier should be provided for that purpose. Adequate space for handling all of the operations connected with general cargo is a prime factor in reducing congestion—the most serious cause of delay and expensive handling cost.

Every effort should be used to eliminate obstructions to the free movement of freight. Where columns are required for the support of the shed structure, the number should be reduced to a minimum. The location of any stationary freight-handling equipment should be carefully considered, with the view of permitting the utmost flexibility of freight movement.

Unless the wide-pier terminal with ample, unobstructed cargo decks is constructed, the handling of cargoes of large ships can be done only at excessive cost and considerable delay. The wide transit shed with its railroad tracks and wagonways for drays and motor trucks has in many respects greater influence upon the expeditious interchange of freight between marine and land carriers than some types of freight-handling devices that cannot be properly adapted to the disposal of the various forms of freight in the general-cargo trade.

At the meeting of the Materials Handling Division of the A.S.M.E. in Philadelphia in December, 1921, a very interesting discussion brought out some of the advantages of two-story pier sheds.

FIG. 3 PIER NO. 27, NORTH WHARVES, PHILADELPHIA, SHOWING BRIDGE FOR SECOND-DECK TRACKS

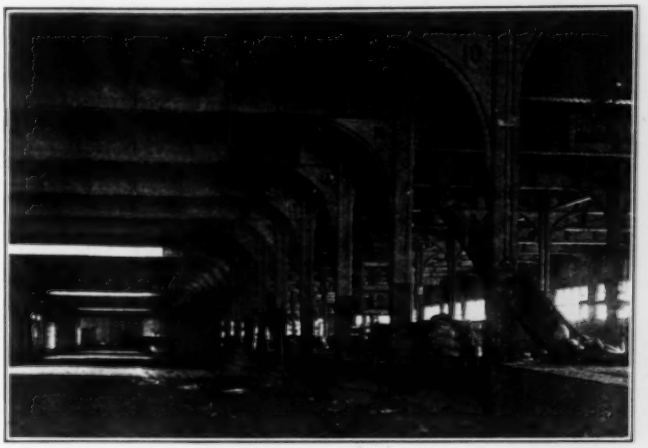


FIG. 4 CENTER CAR TRACKS AND DEPRESSED WAGONWAY ON MUNICIPAL PIER NO. 78, SOUTH WHARVES, PHILADELPHIA

Col. Fred Jaspersen explained the reasons leading up to the building and continued use of double-deck piers at Philadelphia as follows:

When the first pier was built on these lines, the idea was that the lower floor would provide space for the collection of the ship's cargo, which arrived at the terminal at intervals; the merchandise was stored and classified on the lower floor. This left the second floor or upper deck, as it was termed, free to receive the ship's inbound cargo. Tracks on the upper deck of these piers make it as convenient to handle cargo from the upper deck as from the lower. The inbound cargo is classified and loaded into cars on the second floor and as soon as space is available in the ship, the stevedores start loading from the lower floor.

We have found the cost....to be lower in operating this type of pier, because the placing of cargo from the ship's hold to the upper deck was accomplished much quicker than it could have been done if the inbound cargo had been placed on the lower floor. It was found that *an average of three drafts could be placed on the second floor while two were being placed on the lower floor.* This scheme permitted better distribution of the men and employment of greater numbers without interfering with each other, which resulted in greater speed in the discharging and loading of cargo.

The bulkhead shed (which is usually a one-story head house flanking the inshore end of the pier) should prove to be an advantage with a more extensive use of tractors and trailers delivering freight to loading platforms of the shed along the street. It will keep many drays and motor trucks out of the pier altogether and tend to reduce congestion in the pier shed.

Large motor-truck elevators at the street end of the two-story pier shed that will enable local delivery to reach the upper deck direct from the marginal way to receive freight that has been discharged there, will greatly increase the usefulness of this type of structure. This will also avoid the necessity of many teams going on the first deck of the pier.

RAILROAD TRACKS

The solution of securing the quickest dispatch of freight between railroad car and ship is to run the tracks directly on the pier. Depressed tracks (Fig. 4) in the center of the pier form a natural barrier to separate cargo space allotted to each steamship berth and in a sense divide the pier in half, which is a distinct advantage when the pier—or the double pier, as it might be called—is leased to two steamship lines. Two tracks are essential, one for each berth; but in the case of a pier long enough to accommodate two or more ships on each side, one additional running track along the center—or three in all—with crossover connections to the other two about midway in the length of the pier, is desirable to permit of car service to the outshore berths without interfering with cars assigned to, or interrupting the loading or unloading opposite, the inshore berths. Furthermore, the center location of tracks in an emergency, or when one side of the pier is not in use, will permit cars on all the tracks to be loaded or unloaded with freight from the steamship berths on either side of the pier by merely trucking through one line of cars after they have been properly spotted. Another advantage of center tracks is that they permit loading or unloading of cars under cover of the pier shed. In connection with these tracks, it is also desirable to provide a means of attach-

FIG. 5 DEPRESSED APRON TRACK ON MUNICIPAL PIER NO. 78, SOUTH WHARVES, PHILADELPHIA

ing tackle equipment to the overhead structure to facilitate the loading or unloading of heavy parcels of freight from open or gondola cars. Many similar accessories of this character will add greatly to the economy of handling freight in the pier shed.

Apron tracks outside of the pier shed are always desirable, but where the pier width is limited it is questionable whether the covered cargo-deck area should be reduced to permit of their installation. The disadvantage of not having apron tracks for loading or unloading heavy commodities direct between car and ship may be far less serious than the congestion and confusion that would result from the restricted cargo-deck area in a narrow pier shed.

Some difference of opinion exists as to whether apron tracks should be depressed or laid flush with the pier deck. So far as the loading or unloading between ship and cars on the outside tracks is concerned, there is no particular advantage in either method. On the other hand, while the loading or unloading between ship and pier deck is underway, the tracks should be clear of cars, and this would lead to the belief that the tracks should be flush with the pier deck, in order to provide a deck-level place of deposit over the entire width of the apron for the drafts of cargo and also to facilitate trucking in and out of the shed. However, in the case of depressed tracks (Fig. 5), the sunken area outside the shed is not a very serious handicap if a platform space not less than 6 ft. in width and flush with the main pier deck is provided between the sunken pit and the pier shed for the handling of drafts of cargo. In any event, portable platforms laid across and spanning the width of the depression, in line with the loading operations, will provide the deck-level apron for its full width when required. The one great advantage of the depressed apron tracks is their use for bringing freight to the pier, or vice versa, when the berths are not occupied by the ships. When apron tracks are installed they not only can be, but invariably are, used to the greatest extent for transporting car shipments to and from the pier when the ship berths are unoccupied. In fact, their use for this purpose seems to greatly exceed that for loading direct between car and ship, and the importance of the car floors' being level with the main pier deck is obvious and offsets the slight disadvantage of a partially depressed apron for ship-loading operations, which may be readily overcome to a considerable extent, as discussed before.

For unloading or loading open cars on the apron tracks, the equipment installed on the pier for loading the ship would be available.

VEHICULAR TRAFFIC

The other means of bringing goods to and from the pier, particularly the local deliveries, is by motor truck and teams. Ordinarily they cannot be confined to any particular location on the cargo deck, although the tendency is to follow a line of travel adjacent to the center car tracks, especially if the same entrance to the pier is used for both teams and cars. Congestion caused by drays and trucks could be reduced to a great extent by constructing bulkhead sheds, as discussed before.

Where the pier can be built wide enough, a depressed wagonway (Fig. 4) extending into the shed about three-fourths of the pier length will greatly facilitate team and truck delivery to and from the pier. It will not only keep many teams off the cargo deck but will permit loading or unloading of these units from a cargo deck built at wagon-floor height.

Another distinct advantage of the depressed wagonway, particularly with respect to a pier long enough to berth two or more ships, is that it affords a means of team traffic reaching the outshore berths without interfering with the working of freight on the cargo decks at the inshore berths. One car track laid along each side of such a wagonway will preserve the desirable feature of center car tracks—the space between tracks affording a thoroughfare for teams to reach the cargo decks at the outshore berth. When these tracks are not occupied by cars, either totally or partially, the teams can back up to the cargo-deck platform. With a layout of this character, however, it is essential that the pier be not only wide enough to accommodate the depressed wagonway—due to the fact that the space can be used for no other purpose—but, also, it must be wide enough to allow apron tracks to be installed, because the two tracks in the wagonway extending only three-quarters of the length of the pier will not permit of sufficient car service on a four-berth pier.

LOADING AND DISCHARGING SHIPS

The importance of quick loading and unloading of ships, which in turn results in quick turn-around, cannot be overestimated, and any improvements in the existing methods that will at the same time satisfactorily meet the many complexities involved in handling freight at a general-cargo pier, will be a step in the right direction and one that will be welcomed.

As a rule, any discussion of loading or discharging general cargo centers around the efficiency of ship's gear in comparison with wharf

FIG. 6 BURTONING OF CARGO TO THE LOWER DECK OF A PIER WHILE COALING OPERATIONS ARE UNDER WAY WITH SHIP BREASTED OFF

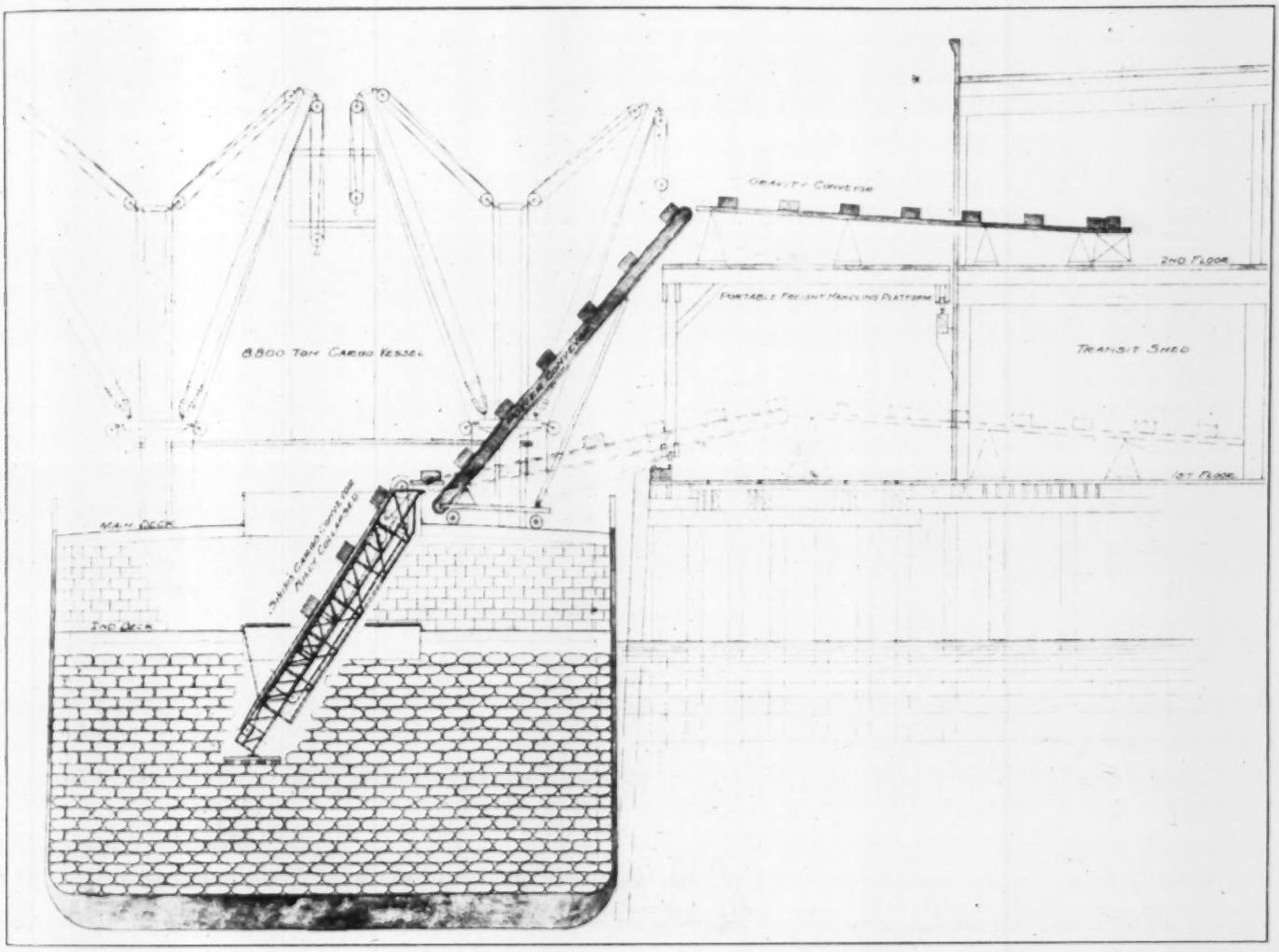


FIG. 7 SHIP'S CARGO TELESCOPIC CONVEYOR, PORT OF SEATTLE, WASH.

cranes. It seems doubtful whether the wharf crane will displace the use of the ship's gear for handling general cargo until the operating and economic advantages of the crane have been demonstrated to be superior to the ship's winches by results of actual tests of each method conducted under working conditions.

Ship's gear forms one of the most flexible methods now in use that will meet all of the requirements for ship loading. It has one distinct advantage of being located on the ship and not on the pier, where space is valuable for other purposes. Its use is well understood and it can be worked over a narrow apron, thus permitting a maximum area of the wharf to be covered over.

Cargo masts on the pier will greatly increase the flexibility of loading with ship's gear in that it can operate by "Burtoning" over a wide apron or when the ship is breasted off (Fig. 6), and also over a greater length of the pier apron. The initial cost of cargo masts is small and there is practically no maintenance expense as there is nothing to get out of order.

In designing the side construction of a pier superstructure to permit of loading operations to be conducted at any point along the ship's berth, continuous door openings should be provided along the full length of the pier, and of a height sufficient to form no interference with the operation of the ship's gear. Generally, it is found that a clear opening of door height should be not less than 20 ft. for the first story. In the second story of the pier shed this height may be reduced, and door openings in alternate bays should provide sufficient access to the second deck for loading or unloading operations.

Remote-control, portable electric dock winches at some piers are desirable for furnishing power to supplement the ship's gear, although cases are known where pier operators have requested the port officials to remove publicly owned winches from the piers on account of the space they require.

Wharf cranes will generally accomplish all of the loading or unloading operations of the ship's gear, but their economy and speed still seem to be questioned. The pier must be built for their support and free operation, and unless the speed of ship loading and discharging is reduced, it is doubtful if they are able to control any more of the wharf area than the ship's gear. A wide apron is necessary, and besides skilful operation is required to avoid the ship's rigging. One drawback to providing wharf cranes on covered general-cargo piers is the high cost of installation and maintenance; another—in some cases—is the additional width of pier that is necessary for their operation.

In the case of a pier where apron tracks are built outside of the shed, it may be good policy to design the foundations and the superstructure for the future installation of semi-portal cranes, in the event of their use being warranted.

Other methods of loading ships, such as the portable conveyor systems, have proven successful at some of our West Coast ports for full cargoes of a uniform character such as bagged flour, but it is very doubtful if stevedores would set up such machines for loading parcel lots and then turn to the ship's gear or cranes for other freight that could not be handled on conveyors. The main objection to any equipment of this kind is the room it takes up on the pier when not in use, and also the necessity of changing to other kinds of equipment in loading miscellaneous cargo.

FREIGHT HANDLING WITHIN THE SHED

The first essential for the economical movement of freight in the transit shed is a large area of unobstructed cargo-deck space. Stationary or semi-stationary equipment will generally prove to be obstructions in the way of flexibility of movement. Speaking on this subject, J. A. Jackson has said:

Industrial trucks and tractors with trailers provide to the fullest extent

that extreme flexibility so necessary and desirable for cargo handling on piers, the industrial truck being the more flexible of the two. If sufficient aisle space can be provided the tractor train is more desirable as it can handle a ton at lower cost than an industrial truck on account of the lower labor charge and due to the fact that the tractor—representing the major part of the investment—can be kept almost constantly at its legitimate work of hauling if sufficient trailers are provided.

The loading and unloading of trailers and trucks is still a job for manual labor and it must be admitted that in respect to this one problem the old hand truck has about everything beaten. It is for this reason that for very short movements the hand truck can make a better showing than either electric trucks or trailers.

Other methods such as overhead traveling cranes and telpher systems usually can operate only within certain restricted areas, particularly in two-deck structures where necessary columns form an obstruction, and the various movable units of either of these systems will invariably interfere with each other. Furthermore, the portable equipment before mentioned—in the event of its not proving satisfactory either generally or for particular purposes—does not represent an exorbitant initial cost and can be very readily removed from the pier if it proves to be unsatisfactory.

For interchange of freight between the first and second decks of a two-story pier shed, the large standard platform elevator and the automatic elevator and lowerator for handling packages of the size and weight for which it is particularly adapted, are the best means of communication; however, in the case of lowering goods from the second deck to the first, full advantage should be taken of the gravity type of equipment, such as chutes. In this connection it is believed that the straight chutes possess more advantages than the gravity spiral conveyors, in that the entire operation of lowering freight can constantly be seen by the operator stationed on the second deck.

Many other minor details in the design of piers, if given proper attention, will facilitate the general freight movement in the pier shed.

If the overhead girders and roof trusses are designed to allow for a moving load of, say, three tons at any point along the bottom chords, there need be no alarm over lifting occasional heavy loads from the pier deck level by means of tackle attached to these structural members; swivel tackle links built on them for such purposes—particularly over the railroad tracks—will prove very helpful in saving time in rigging tackle and at the same time result in such attachments being made to the structure at points where provision has been made in the design for it.

This particular allowance for loading in the design of the pier would also provide for future installations of overhead mechanical equipment that might prove serviceable in specific cases.

Tackle links built along the stringpiece of the apron will permit of easy tackle attachment to the pier for ship-loading operations with dock winches and will also go a long way to prevent lashing to columns, which invariably results in bent and battered door guides.

Links built in the side walls of depressed car pits have proved to be valuable for moving railroad cars with dock winches or other power equipment.

Dr. MacElwee, in a very commendable discussion on The Relation of Wharves and Warehouses in the Economical Handling of Materials, compares the advantages and disadvantages of terminal freight movement in "the pier and warehouse system" with "the quay and warehouse system," and offers the huge pier, or "quay pier," with its transit shed, warehouses, teamway, and railroad tracks as a solution of our water-front terminal problem with respect to the handling of "general" cargo, its chief advantages being the decrease in congestion and the shorter trucking movement.

The adoption of the wide transit shed, with its large, unobstructed cargo-deck area—whether the terminal is of the pier, double-pier, quay or quay-pier type—is obviously the fundamental essential for a successful and economical terminal facility for handling general cargo, and also the feature that will sooner or later permit of more extensive freight handling with mechanical equipment.

The success of any mechanical means of improving our freight-handling problem will be dependent upon the whole-hearted co-operation of all those who have any connection with terminal operation: the mechanical and electrical engineer must play just as important a part as the stevedore, the railroad or steamship operator, the port authority, or the terminal engineer.

Discussion

G. F. Nicholson[1] wrote that on the Pacific Coast freight was handled direct to and from vessels, and while gantry cranes, shearleg derricks, and locomotive cranes were used to handle large-tonnage export commodities such as lumber, iron and steel, both in the raw and manufactured state, when it came to handling imports consisting of boxed, baled, and sacked goods, light portable equipment such as tractors and conveyors were employed.

Ports like that of New York, where a large barge and lighterage business was carried on, should be well equipped with cranes, the straight-line roof type being the best for such work.

In addition to its heavy handling equipment the port of Seattle had a varied assortment of light portable equipment consisting of electric and gasoline tractors and trailers, incline conveyors, stacking elevators, etc. With a view to improving their service the port authorities were now constructing a ship-cargo telescopic conveyor which they had designed themselves, and it was expected that this machine would handle boxed, baled, and sacked goods weighing up to 500 lb. per package twice as rapidly as the equipment now used for that purpose. This conveyor, shown in Fig. 7, it was believed, would do away with the use of slings and the damage often resulting therefrom; permit of much better sorting of cargo to the hold of the vessel, as it could be handled by gravity conveyors to the main conveyor equipment; increase the speed of handling, as a continuous line of freight would be transferred from the hold of the vessel to the pile on this conveyor equipment; and reduce the cost of handling freight, as it would be carried to its destination on the wharf by the conveyor without rehandling.

J. A. Shepard,[2] who opened the oral discussion, called attention to the fact that one of the greatest difficulties in connection with materials handling today was the lack of adequate cost data. His mature opinion regarding the application of machinery to the handling of miscellaneous cargoes was that it could be made sufficiently flexible and could be installed in moderate but sufficient variety to meet all of the reasonable requirements of miscellaneous cargo handling. Too little had been said about cargo-handling machinery in the pier shed, which Mr. Shepard believed was destined to exercise perhaps a greater influence on the total economy than the use of machinery outside the shed. The traveling crane, able not only to hoist its load but to travel in all directions and cover absolutely a large area, he predicted, would in course of time be the solution of the handling problem within the pier shed.

H. E. Birch,[3] referring to the unloading of incoming freight to the upper deck of a double-deck pier, asked whether the cost of rehandling that freight on to the cars on the lower deck was taken into account; also what influence the type of stevedore labor available in any particular port had on the selection of the types of machinery or pier design.

Augustus Smith[4] said that the box car was a tremendous obstacle to any practical crane system, and a great step forward had been taken by the New York Central recently with its container car. The railroad rate system was based on the weight and value of freight and was unscientific. If it were only possible to have it based on the cost of handling, it would be easy to induce, through the Inter-State Commerce Commission, the roads to recognise convenient sizes of packages; and if manufacturers and shippers could be prevailed upon to use standard containers by a freight differential in their favor, a long step forward would be taken in facilitating the handling of such freight.

H. V. Coes,[5] chairman of the Materials Handling Division, who presided over the session, said that in his opinion, it ought to be possible, with the use of high-grade steel, to build a freight car from which the roof could be lifted; this would permit the use of containers of larger size and the tiering of freight, and immediately open up the use of cranes or other material-handling devices. It would also make loading a great deal easier than it was at the present

(*Continued on page 569*)

[1] Chief Engineer and Executive Secretary, Port of Seattle, Seattle, Wash.

[2] Vice-Pres., Ch. Engr., Shepard Elec. Crane & Hoist Co., Montour, N. Y. Mem. A.S.M.E.

[3] Sales Mgr., R. H. Beaumont Co., Philadelphia, Pa. Assoc. Mem. A.S.M.E.

[4] Pres., Bergen Point Iron Wks., Bayonne, N. J. Mem. A.S.M.E.

[5] Mgr., Ford, Bacon & Davis, Philadelphia, Pa. Mem. A.S.M.E.

The Determination of Chimney Sizes

By ALFRED COTTON,[1] ST. LOUIS, MO.

In this paper the author presents a simple and orderly system, based on accepted characteristics, for determining the sizes of chimneys. He has found that certain essential relations exist between capacity, draft, diameter, and height when connected in the manner described in the text.

Under any specific conditions there is a definite static draft for a given height and a definite "maximum capacity" for any given diameter. These are connected by a fundamental curve which is applicable to all chimneys under all conditions.

Charts are provided which give the static draft and maximum capacity of chimneys up to 500 ft. high and 25 ft. diameter, from which the working draft and capacity are found by means of the fundamental curve. Other charts give factors for various atmospheric temperatures, for altitudes; and for approximate work based on boiler horsepower. A problem is worked out to facilitate an understanding of the system.

IT IS PROBABLE that no engineering subject is in such a chaotic state as that of chimneys. While much excellent work has been done and many formulas, tables and charts have been prepared, chimneys are nevertheless usually designed by rule of thumb, and there are plenty of cases where their performance is either much greater or much less than was expected.

It is believed that the method of proportioning chimneys outlined in what follows has the merit of giving definite sizes which are entirely free from conjecture, in a very simple and consistent manner.

Description of the Method

It is convenient to consider the available draft at the chimney base as being the static draft less the draft lost by chimney friction and by acceleration of the gases, and this must equal or exceed the draft necessary to operate the boiler, etc.

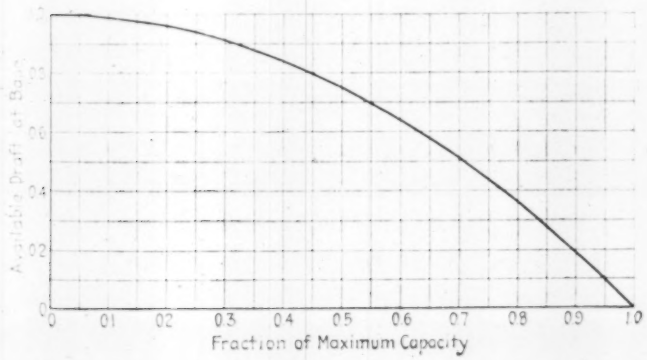


Fig. 1 Relation of Draft Fraction to Capacity Fraction (Available Draft Ratio)

The static draft is the vacuum prevailing under an imaginary condition when no gases are flowing. It is an absolutely definite quantity for any given circumstances and forms the starting point of this method.

The chimney friction varies as the square of the velocity of the gases. If the velocity is progressively increased, a point is reached where the chimney friction is equal to the static draft. This is the "maximum capacity," and it is just as absolute and definite a quantity for any given circumstances as is the static draft from which it is determined, and it forms the end point of the method.

The draft loss due to chimney friction is in direct proportion to the height of the chimney. So also is the static draft. If we double the height of the chimney, we double both the static draft and the draft loss, and the maximum capacity is unaltered.

Since the chimney friction increases as the square of the velocity of the gases, the resulting curve is a parabola in all cases. This curve is presented in Fig. 1, and relates the load expressed as a fraction of the maximum capacity to the available draft expressed as a fraction of the static draft. This is a fundamental curve which applies to all chimneys at all temperatures of gases and of the atmosphere and at all altitudes.

Static Draft

Figs. 2 and 3 give the static draft for chimneys 100 to 500 ft. high at sea level dealing with gases up to 1200 deg. fahr. in temperature when the atmosphere is at 60 deg. Another chart in the complete paper deals similarly with chimneys from 0 to 100 ft. in height. Fig. 4 gives factors with which to multiply the static draft found from Figs. 2 and 3 to obtain the static draft for atmospheric temperatures other than 60 deg.

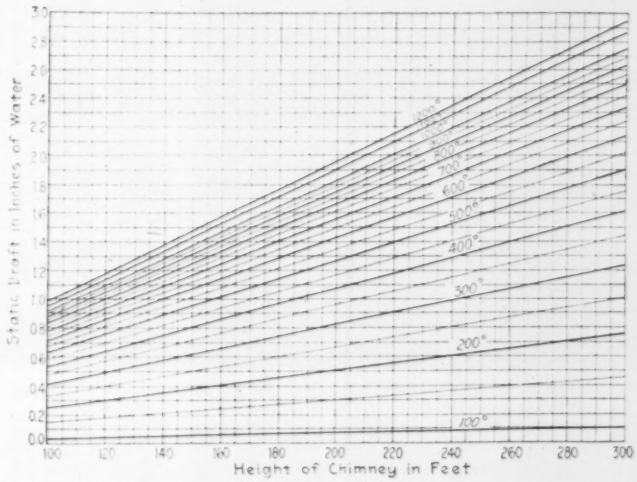


Fig. 2 Static Draft of Chimneys from 100 to 300 Ft. High with Gas Temperatures from 100 to 1200 Deg. Fahr. at Sea Level with Atmosphere at 60 Deg. Fahr.

(Curves marked with mean temperature of gases in chimney in deg. fahr.)

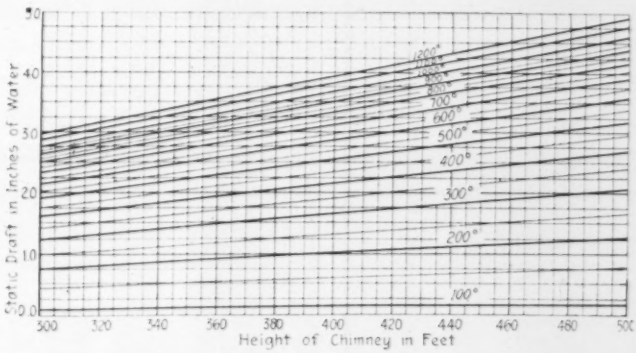


Fig. 3 Static Draft of Chimneys from 300 to 500 Ft. High with Gas Temperatures from 100 to 1200 Deg. Fahr. at Sea Level with Atmosphere at 60 Deg. Fahr.

(Curves marked with mean temperature of gases in chimney in deg. fahr.)

Temperature of Gases in Chimney

The author's article on Loss of Heat in Brick Chimneys, published in *Power Plant Engineering*, Aug. 1, 1921, and which forms an appendix to the complete paper, includes some curves of temperature drop. These lead to the factors of Fig. 5, by which the mean temperature in the chimney may be found.

Altitude and Static Draft

The static draft at any barometric pressure B in inches of mercury is that at sea level multiplied by $B/30$. If the same load is to be carried at altitude as would be carried at sea level, then the same weight of gases must be dealt with. Since the density of

[1] Chief of research department, Heine Boiler Co. Mem. A.S.M.E.

Contributed by the Fuels Division and presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

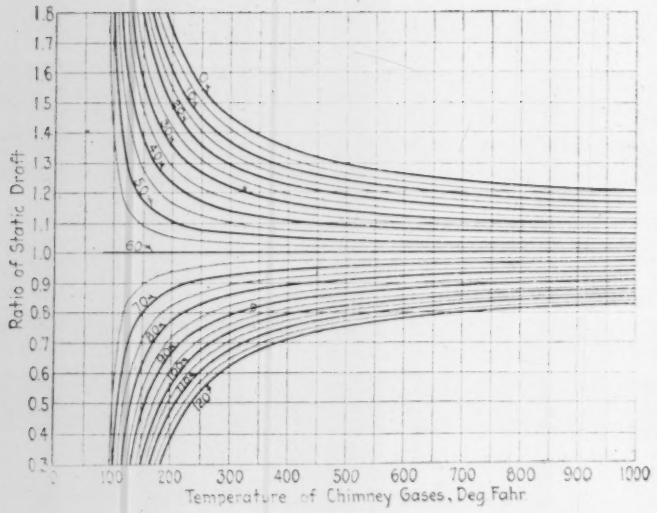


FIG. 4 RELATION OF STATIC DRAFT OF CHIMNEYS WITH TEMPERATURES OF ATMOSPHERE FROM 0 TO 120 DEG. FAHR. TO THAT AT 60 DEG. FAHR. (Curves marked with temperature of atmosphere in deg. fahr.)

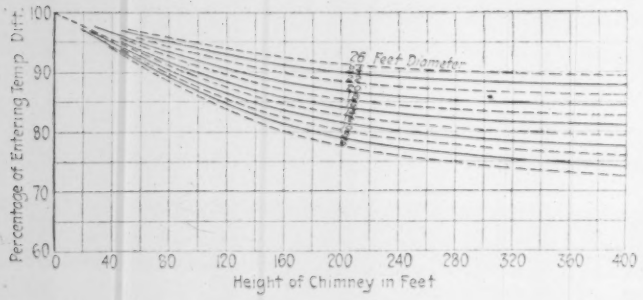


FIG. 5 FACTORS FOR FINDING THE MEAN TEMPERATURE OF THE GASES IN CHIMNEYS

PROCEDURE (Masonry Chimneys):

A = observed temperature of atmosphere
E = observed temperature of gases entering chimney
P = percentage appropriate to diameter and height as read from chart
G = temperature of gases entering chimney above that of atmosphere
$= E - A$
C = average temperature of gases in chimney above that of atmosphere
$= G \times P$
$C + A$ = average temperature of gases in chimney.

the gases is less, their velocity must be higher, and the height of chimney necessary at altitude to provide sufficient draft to do the same work as at sea level, will be the sea-level height divided by $(B/30)^2$, or multiplied by its reciprocal which is given in Fig. 6.

MAXIMUM CAPACITY

Menzin, in his paper on Proportioning Chimneys on a Gas Basis, Trans. A.S.M.E., 1916, went so carefully over all the available data on chimney friction that the formula he presented has been used. Fig. 7 gives the maximum capacities of chimneys from 5

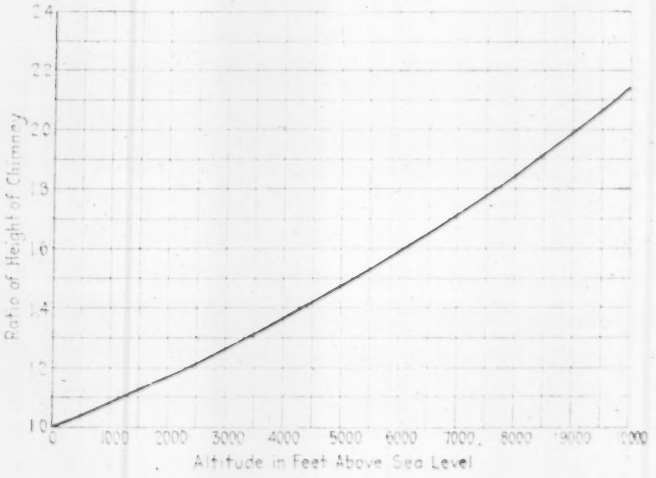


FIG. 6 EFFECT OF ALTITUDE ON HEIGHT OF CHIMNEYS

to 25 ft. in diameter for various mean temperatures of gases with the atmosphere at 60 deg. at sea level. Other charts in the complete paper cover the range for diameters of from 0 to 10 ft. The maximum capacities as read from Fig. 7 are to be multiplied by the appropriate factor read from Fig. 8 when the atmospheric temperature is other than 60 deg. fahr.

It is convenient to assume that the velocity of the gases remains constant. Then the maximum capacity at altitude is that at sea level multiplied by $B/30$.

ACCELERATION OF GASES

The pressure difference required to accelerate the gases is conve-

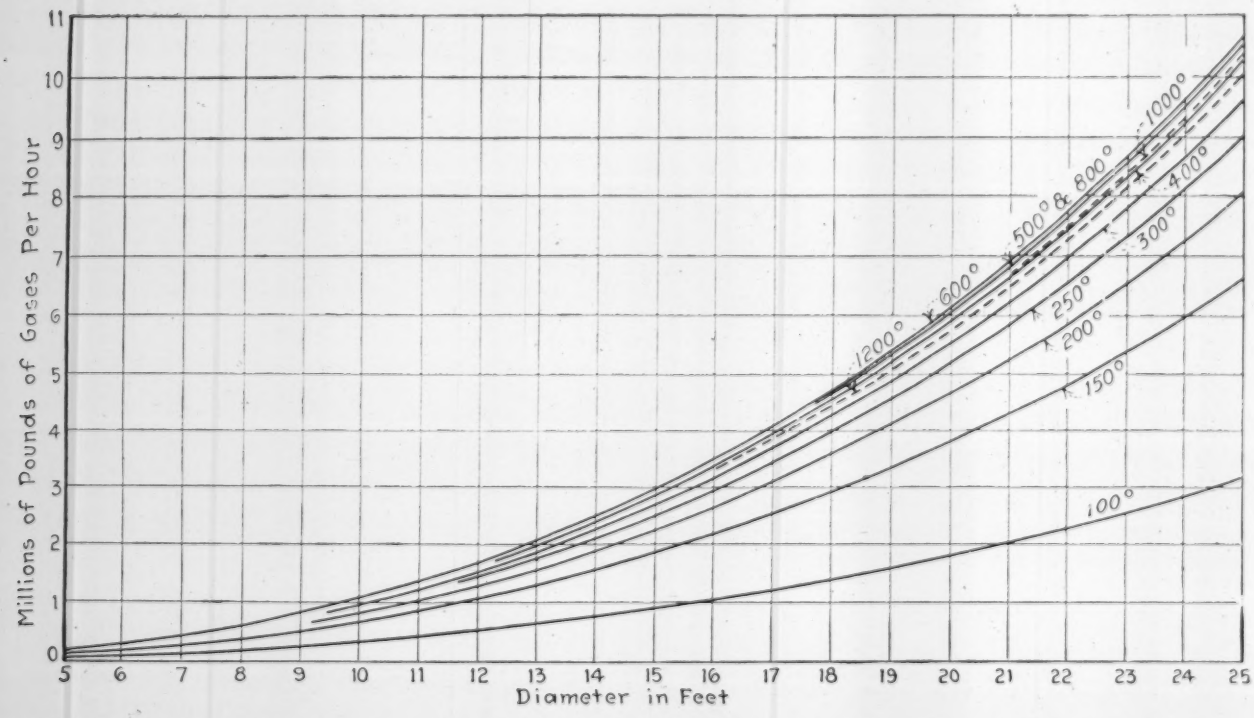


FIG. 7 MAXIMUM CAPACITY OF CHIMNEYS FROM 5 TO 25 FT. IN DIAMETER AT DIFFERENT GAS TEMPERATURES FROM 100 TO 1200 DEG. FAHR. AT SEA LEVEL WITH ATMOSPHERE AT 60 DEG. FAHR.

iently stated as draft loss, and curves showing this draft loss at maximum capacity for each diameter have been drawn in Fig 9, for different temperatures. Other charts in the complete paper covers the range for diameters of from 0 to 10 ft. The fraction of the draft loss for any desired fraction of the maximum capacity is the same for all maximum capacities. Fig. 10 gives this fraction.

The draft loss at sea level multiplied by $B/30$ gives the draft loss for altitudes.

Available Draft

Enter Fig. 1, with the ratio of available draft to static draft, and read the fraction of maximum capacity. Divide the required weight of gases by this fraction and use the resulting maximum capacity to find the requisite diameter. Or with given diameter, read the maximum capacity and state the required capacity as a fraction of it. Divide the required draft by the fraction read from

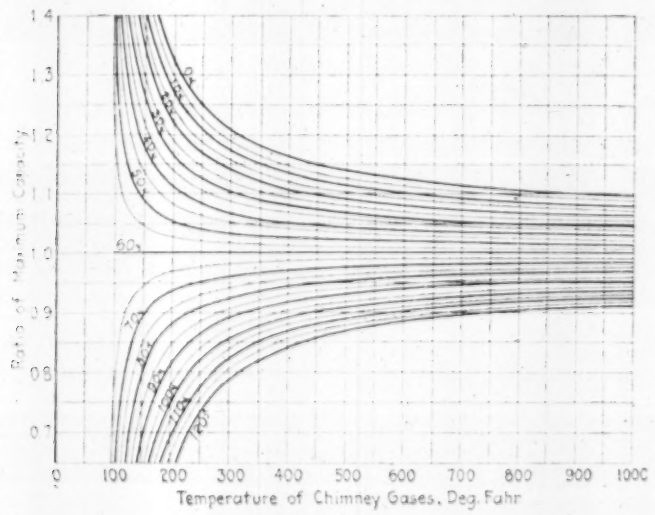


Fig. 8 Relation of Maximum Capacity of Chimneys with Temperatures of Atmosphere from 0 to 120 Deg. Fahr. to That at 60 Deg. Fahr.

(Curves marked with temperature of atmosphere in deg. fahr.)

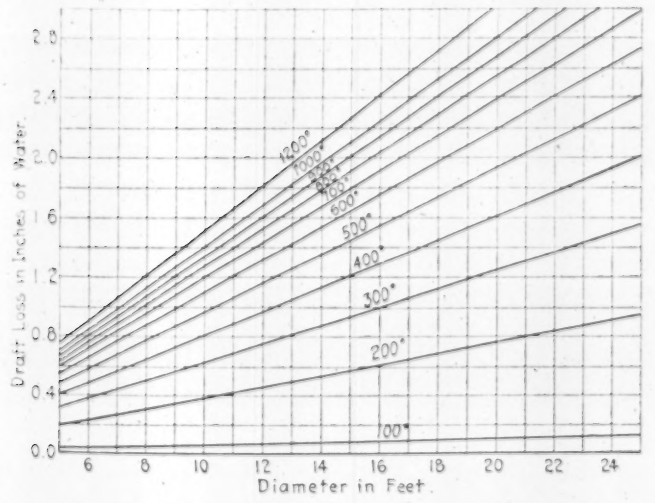


Fig. 9 Draft Loss Due to Acceleration of Gases at Maximum Capacity of Chimneys from 5 to 25 Ft. in Diameter with Temperatures of Gases from 100 to 1200 Deg. Fahr. at Sea Level

(Curves marked with mean temperature of gases in chimney in deg. fahr.)

Fig. 1 and get the equivalent static draft. Add the draft required to accelerate the gases and read the height of chimney from Fig. 2 or Fig. 3. Several combinations of height and diameter can be found for any circumstances very quickly.

Draft Required

The draft required at the base of the chimney is made up as follows:

1 *Vacuum Over Fuel Bed.* Fig. 11 shows the vacuum required in the furnace chamber for burning various fuels. The values are fair averages which accord with the author's experience with reasonably clean fires when hand firing and with average conditions of stoker operation. The broken-line curves were kindly supplied by Mr. Thomas A. Marsh, Mem. A.S.M.E. With forced draft, a vacuum over the fire of about 0.1 in. should be maintained.

2 *Draft Loss Through Boiler Setting.* A curve should usually

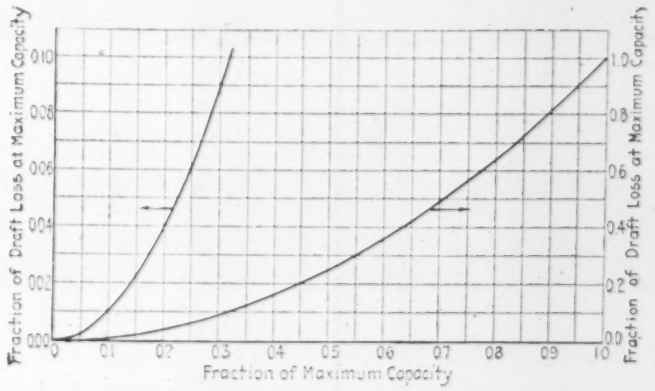


Fig. 10 Relation of Draft-Loss Fraction Due to Acceleration of Gases to Capacity Fraction

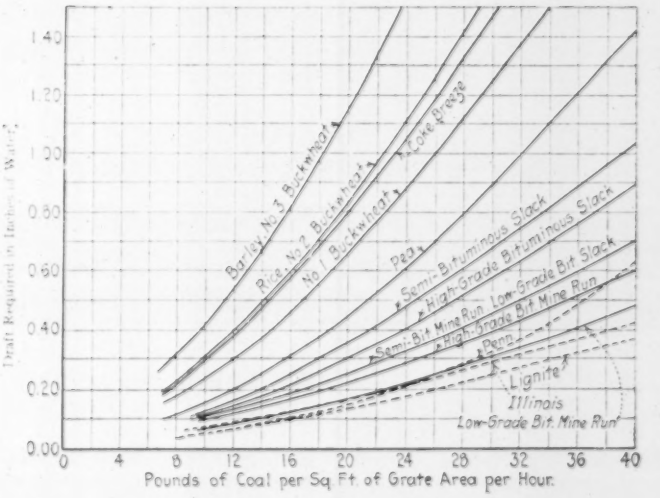


Fig. 11 Draft Loss through Fuel Bed with Different Fuels

(Note—Broken-line curves are for coal burned on chain-grate stokers and as drawn by Green Engineering Co.)

be obtained from the boiler manufacturer based on some proportion of excess air with the fuel to be used.

The draft loss through a horizontal, diagonally baffled, 14-high water-tube boiler burning bituminous coal with 13 per cent of CO_2 in the flue gases is given in Fig. 12.

The effect of an alteration in the amount of excess air as indicated by the proportion of CO_2 in the flue gases is shown approximately by the curves drawn in Fig. 13. Precise factors are not possible, but these are sufficiently accurate for the present purpose. The draft loss for any percentage of CO_2 is to be multiplied by the appropriate factor to find the draft loss at some other percentage of CO_2.

3 *Draft Loss Through Damper.* Some may prefer to allow a little draft loss through the damper, the damper being not fully open, as a factor of safety. But this is quite unnecessary with the method of treatment being described. Of course, in some ill-designed plants there may be a real draft loss through the damper frame owing to its being too small, or through the damper's causing serious distortion of the stream lines when fully open.

4 *Draft Loss Through Flues.* The draft loss through flues is commonly taken as 0.1 in. of water for each 100 ft. of length and 0.05 in. for each right-angle turn. This value results in the curves of gas weights and velocities of Figs. 14 and 15 for a temperature of 540 deg. and for rectangular flues whose sides have a ratio of 2 : 1. Other figures in the complete paper give factors for finding the weight and velocity at other temperatures for the same draft loss, and the effect of the shape of the cross-section of the flue. A

further development results in the curves of Fig. 16 which are based on the gas weights of Table 1.

TABLE 1 WEIGHT OF FLUE GASES PER BOILER HORSEPOWER

Conditions	Pounds of gases per hp.
Coal, natural draft	90
Coal, forced fraft	60
Natural gas	60
Oil	45
Blast-furnace gas	100

The loss due to elbows is generally assumed as 0.05 in. for right-angle turns whose inside radius is not less than the width of the flue.

The effect of different amounts of excess air on the draft loss in flues is the same as for the boiler setting as shown by Fig. 13.

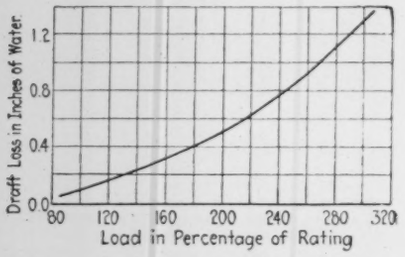


FIG. 12 DRAFT LOSS THROUGH DIAGONALLY BAFFLED BOILER 14 TUBES HIGH WITH SUPERHEATER, BURNING BITUMINOUS COAL WITH 13 PER CENT OF CO_2 IN FLUE GASES, AT SEA LEVEL

WEIGHT OF GASES

The weight of gases to be dealt with from any given fuel depends upon the proportion of excess air. It is convenient to calculate the weight of gases with different proportions of excess air per

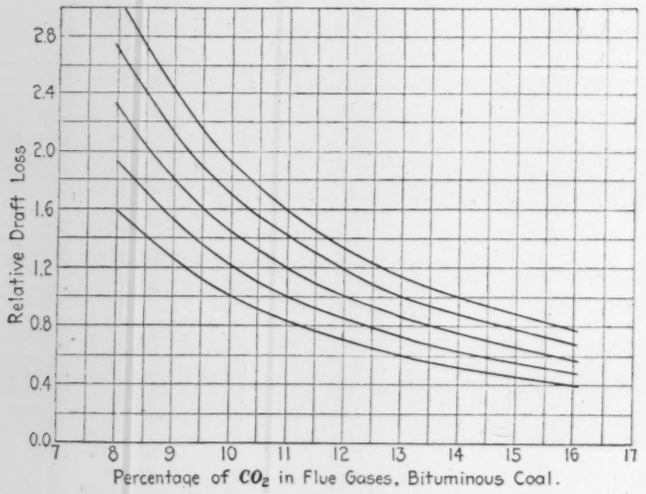


FIG. 13 RELATIVE DRAFT LOSS THROUGH BOILERS BURNING BITUMINOUS COAL WITH VARYING PROPORTIONS OF EXCESS AIR AS INDICATED BY THE PERCENTAGE OF CO_2 IN THE FLUE GASES

pound of "combustible." Any percentage of refuse, including unburned coal going to the ashpit, can then be used to find the weight of gases per pound of dry coal or of coal "as fired." The efficiency of the boiler and furnace will determine the weight of coal per horsepower or per unit weight of steam, and the weight of coal to be burned can then be found.

INDUCED DRAFT

Chimneys for induced draft are computed in exactly the same manner as in other cases. Since it often happens that loads are increased later owing to the ease of doing so with induced draft, it is advisable to allow at least 0.2 in. of available draft at the fan discharge.

APPROXIMATE SIZES

Fig. 17 is drawn for a working capacity of 30 per cent of the maximum capacity. The natural-draft curve is computed at 90 lb. of gases per boiler hp., the forced-draft curve at 60 lb., and the oil-burning curve at 45 lb.

Fig. 10 shows that at 0.3 of maximum capacity the draft loss due to acceleration of gases is 0.09 of that at maximum capacity, or, say, 0.10 for use in this approximate way. Fig. 1 shows that the available draft at 0.3 of maximum capacity is 0.91 of the static draft. Therefore the draft required at the chimney base divided by 0.9, for this approximate work, and added to the draft loss due to acceleration of gases gives the required static draft. The necessary height of chimney can then be directly read from Fig. 2 or Fig. 3 after making due allowance for temperature drop with the aid of Fig. 5.

The accuracy of the results depends only upon that of the constants. For all ordinary cases only a few of the charts are used, and it is an exceedingly simple matter to solve any problem.

CHIMNEY STUDY

A central power station is to have groups of four 1400-hp. boilers to each chimney. The boilers are to be 14 tubes high and are to carry peak loads of 300 per cent of rating when the exit gases will be at 640 deg. Forced-draft stokers are to burn bituminous coal of known analysis with 30 per cent of excess air.

An approximate idea of the chimney is first arrived at. The total horsepower to be handled is 16,800, for which a diameter of 16 ft. is read from Fig. 17.

The draft required at the base of the chimney is found to be 1.55 in., made up of 1.3 in. draft loss through boiler (from Fig. 12), 0.15 in. draft loss through the flues, and 0.1 in. vacuum over the fire. Dividing this by 0.9 gives 1.72 in. as equivalent static draft, to which is added an assumed 0.1 in. for acceleration of gases, making a total static draft of 1.82 in. Assuming a mean temperature of chimney gases of 550 deg., a height of 270 ft. is found from Fig. 2.

The combustion data for the coal are worked out and the total weight of gases per pound of combustible found. Using the predicted boiler and furnace efficiency, the weight of combustible per hour is found and then the weight of gases per hour. Tabulation of data is then commenced as in Table 2, using a number of diameters above and below the first approximation. The first approxi-

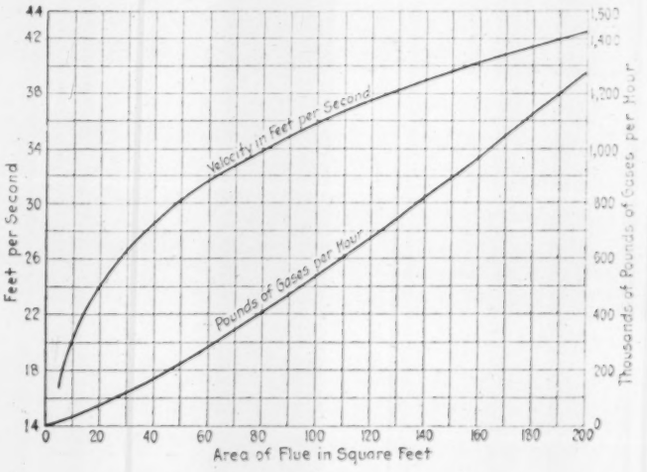


FIG. 14 WORKING CAPACITY OF RECTANGULAR FLUES FROM 0 TO 200 SQ. FT. IN CROSS-SECTIONAL AREA WITH SIDES IN RATIO OF 2:1 WITH GASES AT 540 DEG. FAHR. AT SEA LEVEL, GIVING A DRAFT LOSS OF 0.1 IN. OF WATER PER 100 FT. OF LENGTH

mation of heights appropriate to the listed diameters is given in column 7 and is made on the assumed mean temperature and gas acceleration loss. A close determination is now made of mean temperature in accordance with each combination of approximate height and diameter and of the actual loss due to acceleration of gases. This leads to a new series of heights as entered in column 15. A curve of heights as in column 15 is now drawn against the diameters of column 1 as the full line of Fig. 18 and simplifies the final choice. Such a curve shows the practical limits at each end of the series very decidedly.

It was pointed out by Deinlein that of a series of possible chimneys, the one whose product of diameter by height was the smallest would be the least expensive. These products are entered in column 19 of Table 2 and their curve drawn in Fig. 18 as the broken line. The lowest point in this curve occurs at 14 ft. 6 in. diameter where the height is 289 ft. The author is indebted to Mr. George H. Gibson, Mem. A.S.M.E., for this information.

A problem frequently met with is that of modernizing and

increasing the steaming capacity of a plant while using the existing chimney.

A curve of exit gas temperatures is first drawn and then a curve of the corresponding mean temperatures of the chimney gases as in Fig. 19. These are used to determine the characteristics of the chimney as in Fig. 20; and as this is based on weight of gases, it must be related to Fig. 19, which necessitates a curve of gas weight per horsepower depending on the curve of efficiency. The draft loss through the boilers is determined and plotted. The areas and arrangement of flues are carefully examined because desirable reduction of their draft loss can usually be made by redesigning them. The predicted flue draft loss added to the boiler draft loss and to the vacuum necessary over the fire, will enable the curve of draft required at base of chimney to be drawn as in Fig. 19. With the mean temperature of chimney gases, the static draft for different loadings is read from Fig. 2 and plotted.

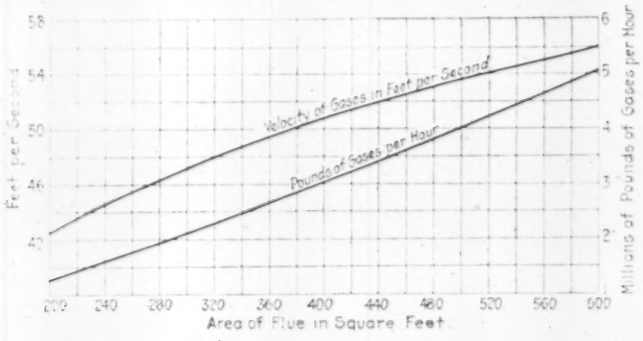

Velocity of Gases in Feet per Second
Pounds of Gases per Hour
Millions of Pounds of Gases per Hour
Area of Flue in Square Feet

FIG. 15 WORKING CAPACITY OF RECTANGULAR FLUES FROM 200 TO 600 SQ. FT. IN CROSS-SECTIONAL AREA, WITH SIDES IN RATIO OF 2 : 1 WITH GASES AT 540 DEG. FAHR. AT SEA LEVEL, GIVING A DRAFT LOSS OF 0.1 IN. OF WATER PER 100 FT. OF LENGTH

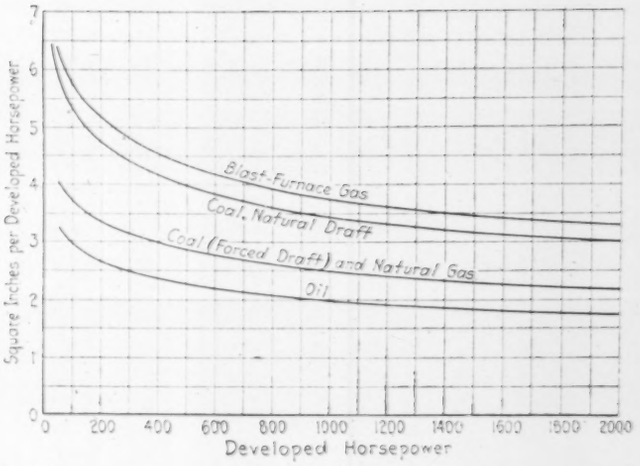


FIG. 16 AREA OF RECTANGULAR FLUES IN SQ. IN. PER DEVELOPED HORSEPOWER WITH SIDES IN RATIO OF 2 : 1 WHICH WILL GIVE A DRAFT LOSS OF 0.1 IN. OF WATER PER 100 FT. OF LENGTH AT SEA LEVEL

The fraction of static draft for different fractions of maximum capacity is found from Fig. 1, and the equivalent draft for each percentage of boiler rating noted. The loss due to acceleration of gases is then found and deducted therefrom, leaving the available draft at the base of the stack at each percentage of rating at which the boilers might be worked. Curves are then drawn of these available drafts as in Fig. 20. The draft required at different ratings is read from Fig. 19 and enables the broken-line curve of maximum chimney load at different boiler-rating loads to be drawn in Fig. 20.

The actual boiler hp. which the chimney will carry at different boiler ratings is obtained by dividing the total gas weights of

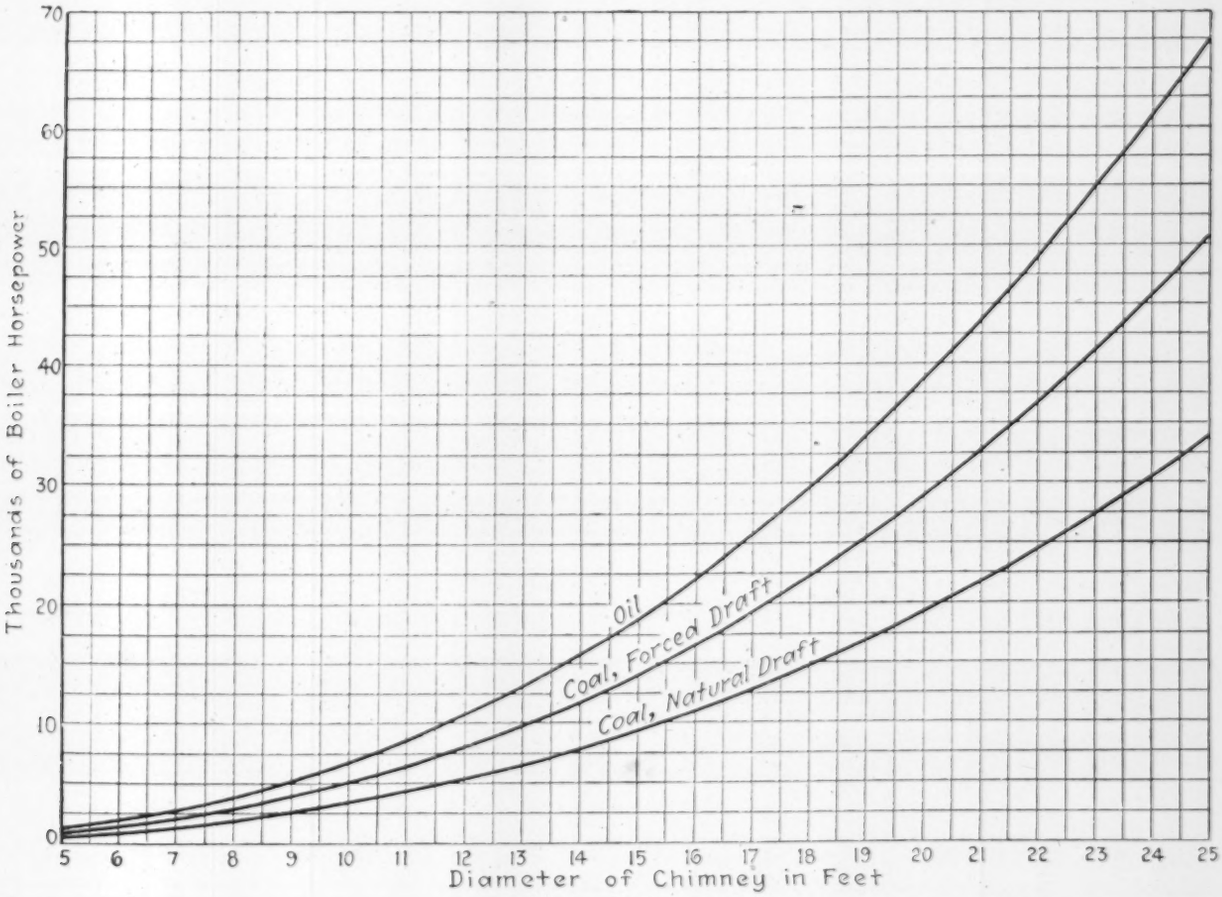


FIG. 17 WORKING CAPACITY OF CHIMNEYS FROM 5 TO 25 FT. IN DIAMETER, BASED ON BOILER HP. WITH ATMOSPHERE AT 60 DEG. FAHR. AT SEA LEVEL

(Maximum capacity = 95 per cent of maximum capacity with mean temperature of gases at 900 deg. fahr. Working capacity = 30 per cent of maximum capacity (or 28.5 per cent of maximum capacity at 600 deg. fahr.). Weight of gases = 90 lb. per hr. for natural-draft coal, 60 lb. per hr. for forced-draft coal, and 45 lb. per hr. for oil, per boiler hp.)

Fig. 20 by the gas weight per hp. of the curve of Fig. 19. To show this more clearly, the curve of Fig. 21 may be drawn. This curve emphasizes how the chimney capacity is governed by the draft loss of the boilers and flues. If the flues were enlarged, the chimney capacity would be greatly increased. This curve also shows that the capacity of the chimney is increased enormously if the boilers are run at low ratings owing to the much lower draft loss at low loads.

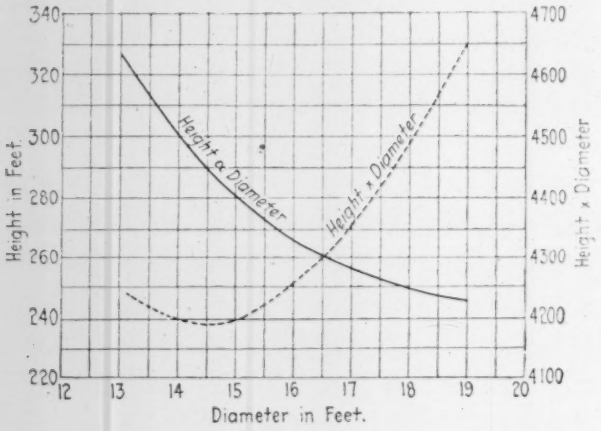


FIG. 18 CHIMNEY STUDY GIVING A SERIES OF COMBINATIONS OF HEIGHT AND DIAMETER

The requirements may be met by reducing the excess air, by improved methods of firing, by installing induced draft, or by adding more boilers and running at lower boiler ratings. The first and last methods increase boiler efficiency and save coal, while the second method increases the coal consumption by running at higher boiler ratings where the efficiency is lower.

Other examples are given in the complete paper which show that the system is as well adapted for finding approximate but reliable chimney sizes as it is for making more accurate studies of chimney characteristics for large and important plants such as the one immediately preceding.

Discussion

THE discussion was opened by the reading of a communication from Julian C. Smallwood[1] in which he pointed out that the author's method was an elaborate structure based on two slender supports, namely, Menzin's coefficient for frictional resistance in chimneys, and the author's estimate of mean temperatures of chimney gases.

Menzin had assumed the hydraulic equation for friction to hold, although there was no experimental proof that for such large gas flows as those in present-day chimneys that it did hold; and had selected the coefficient 0.008 as a compromise between 0.012, from the crude experiments of Gale, and 0.006, from the limited data of Peclét, both obtained prior to 1890 and therefore scarcely up to date.

The author's calculations for chimney height were based on mean stack temperatures instead of temperatures at the base of the stack, which was a correct procedure. Curves were presented in the paper to show the relation between mean temperature of stack gases and temperature at base. These curves were based on experiments made at the Massachusetts Institute of Technology and still more recent ones at Johns Hopkins University. Professor Smallwood could not speak for the former, but having himself conducted the latter experiments, he wished to emphasize the fact that the temperature gradients obtained had been influenced not only by air infiltration through idle boilers but by leakage at the joining of the breeching and the chimney. This possibly accounted for the rapid temperature drop of the gases upon leaving the breeching, as shown by Figs. 2, 3, and 4. As had been pointed out in the report of the Johns Hopkins tests, it was absolutely essential for correct chimney design that the mean stack-gas temperature be calculated with some degree of precision, and that loading of the chimney by cold air be prevented. If the author had given the Johns Hopkins tests much weight, his results would possibly be more applicable to chimneys leaking air at the base than to the tightly sealed chimneys of modern large power plants.

Professor Smallwood questioned the author's statement that the maximum capacity of a chimney was independent of its height. This might be true if the stack gases would only remain at a constant temperature; as a matter of fact they inevitably decreased, radiation alone being sufficient to account for this phenomenon. The higher the chimney, the lower became the temperature of the issuing gases. As the temperature fell, the density of the gases increased, and the increment of draft due to each increment of height became less and less. On the other hand, the frictional resistance per increment of height remained constant, and in consequence there was a limit beyond which the increased frictional resistance was greater than the increased draft, resulting in a lessening of available draft at the base, and in capacity.

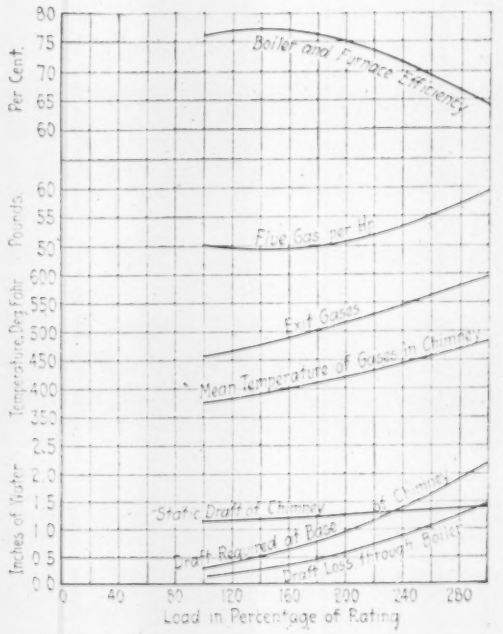


FIG. 19 CHIMNEY STUDY. PERFORMANCE DATA OF AN EXISTING CHIMNEY

[1] Assoc. Prof. Mech. Eng., Johns Hopkins Univ., Baltimore, Md. Mem. A.S.M.E.

TABLE 2 CHIMNEY STUDY

(1) Diameter in feet	(2) Maximum capacity as in Fig. 7	(3) Working capacity = fraction of maximum capacity	(4) Draft required, fraction of static draft	(5) Draft required, 1.55 in. ÷ col. (4)	(6) Static draft required = col. (5) + 0.1 for gas acceleration	(7) Height with mean temperature at 550 deg. fahr.	(8) Factor for mean temperature	(9) Mean temperature difference	(10) Mean temperature of chimney gases	(11) Draft loss by gas acceleration at maximum capacity	(12) Fraction of gas acceleration at working capacity	(13) Gas acceleration at working capacity	(14) Total static draft required	(15) Height required at mean temperatures of col. (10)	(16) Factor for mean temperature	(17) Mean temperature difference	(18) Mean temperature of chimney gases	(19) Product of height by diameter
13	2,000,000	0.429	0.815	1.902	2.002	297	0.795	461	521	1.30	0.183	0.238	2.140	327	0.792	459	519	4251
14	2,380,000	0.360	0.870	1.782	1.882	280	0.805	467	527	1.40	0.130	0.182	1.964	300	0.803	466	526	4200
15	2,820,000	0.304	0.908	1.707	1.807	268	0.815	473	533	1.51	0.092	0.139	1.846	280	0.814	472	532	4200
16	3,320,000	0.258	0.932	1.663	1.763	261	0.824	478	538	1.62	0.066	0.107	1.770	266	0.824	478	538	4256
17	3,860,000	0.222	0.950	1.632	1.732	257	0.833	483	543	1.73	0.049	0.085	1.717	256	0.833	483	543	4352
18	4,450,000	0.193	0.962	1.611	1.711	253	0.841	488	548	1.84	0.037	0.068	1.679	249	0.842	488	548	4482
19	5,090,000	0.169	0.971	1.596	1.696	251	0.849	492	552	1.95	0.028	0.055	1.651	245	0.850	493	553	4655

Despite the preceding criticisms, Professor Smallwood considered that the author had made a real contribution toward the solution of the problem of chimney proportioning and that his method of arriving at definite results was by far the best yet presented. It was of the highest importance, however, that additional experimental data be obtained, and power-plant superintendents should cooperate in experimenting on large chimneys to determine friction losses, the factors with which they vary, and the laws relating them; determining the exact relation between temperature of gases and height of chimney; and investigating the influence of air infiltration, down drafts, stratification, eddy currents, etc. Until this was done, chimney design must remain much where it was.

T. A. Marsh[2] wrote that chimneys were not power generators and were not subject to classification on a horsepower basis. They fulfilled the same function as fans and should be rated by the same units of measurement, namely, gas volumes and pressures.

The large problem was one of judgment as to what variables to use. Such items as the flue-gas temperature as affected by operating conditions, friction losses as affected by fouling of boiler passes, quality of coal and provision for worst coal as affecting the weight of air, were all subject to considerable variation, and judgment based on ample experience was required to select the proper values. There was also the question of the probable operating conditions that might exist five or ten years hence in the plant in reference to plant development and growth, as well as that of the capital investment for plant expansion.

E. L. Hopping,[3] who opened the oral discussion, said that some

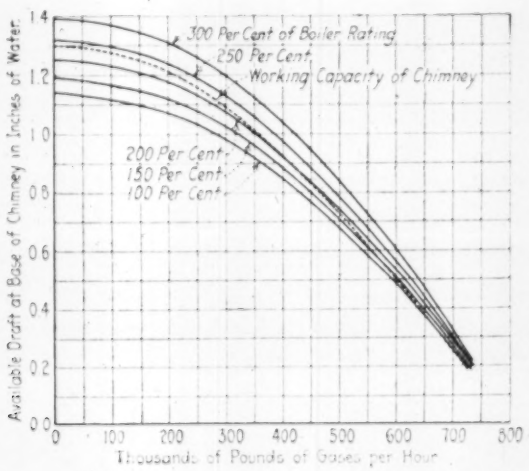


FIG. 20 CHIMNEY STUDY. WORKING LOAD OF AN EXISTING CHIMNEY AT DIFFERENT BOILER RATINGS

years ago he had occasion to design the stacks for a modern plant, and found that the various formulas available for that purpose gave stack diameters ranging from 8 to 12 ft. for a given case. The old stack formulas, which were based on hand firing, would not apply to the great variety of conditions obtaining in stoker firing, and in this respect he felt that the author had presented something definite that could be depended upon.

Great care had to be exercised in making assumptions regarding gas conditions—whether they would be uniform throughout the stack or whether considerable excess air would filter in at some intermediate point. Further, radiation losses would be greater in steel stacks than in those built of brick unless the former were lined from bottom to top.

N. E. Funk[4] said that while two of the fundamental quantities used in the author's method were assumptions based on scanty experimental data, he nevertheless believed that it would be found to yield more accurate results than anything else published on the subject. The formula for friction might be open to question as the friction varied with the condition of the surface, and the surfaces differed widely as regarded roughness. The velocity to be used in such calculations was that at the sides of the stack where the friction occurred, and not the average velocity of flow through the stack cross-section, which was higher.

A. G. Christie[5] confirmed what Mr. Hopping had said in regard to the diversity of results obtained from various stack formulas. The previous summer, in connection with the design of chimneys for the pulverized-fuel-burning station being constructed in St. Louis, he had had some of his assistants gather a large amount of

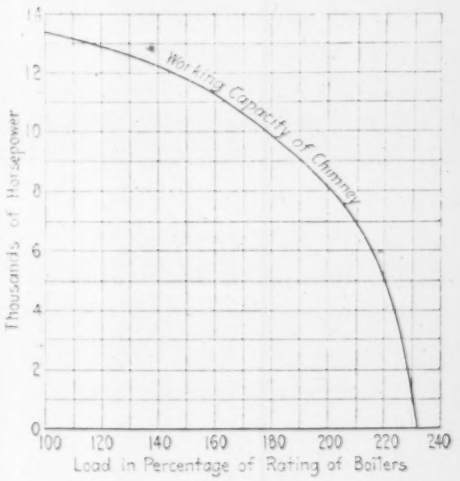


FIG. 21 CHIMNEY STUDY. REDUCTION OF WORKING CAPACITY OF AN EXISTING CHIMNEY AT INCREASED BOILER RATINGS

performance data from chimneys in modern plants in order to determine whether an empirical formula might be derived that would be suitable for the work in hand, and it had been found that practically every chimney considered had been designed, with certain modifications, according to Kent's original formula.

Professor Christie agreed with Mr. Funk that surface friction was involved as well as fluid friction. In the work which Professor Smallwood had conducted at Johns Hopkins, thermocouples having been found untrustworthy, a large resistance thermometer had been built to measure the average temperature across the chimney. This fitted the inside of the stack nicely and could be lowered from top to bottom. For a long time no explanation had offered itself as to the very great temperature drop that took place between the outlet of the boiler and the top of the stack; but at last it was found that the breeching had been cemented into the stack cold, and that heating had dished it inward from the chimney, leaving large openings through which cold air entered. Consequently the published results of the Johns Hopkins experiments would have to be used with a considerable measure of caution as they did not represent good chimney conditions.

While there were many variables involved in chimney design, Professor Christie concluded, all but a few were unimportant and could be neglected. Certain definite items such as velocity, mean temperature difference, and friction loss could be determined, and then three or four of the important variables might be selected and some real experimental data obtained on them which would make it possible to design a chimney with a reasonable degree of accuracy.

F. F. Uehling[6] said that air infiltration between the boiler and stack, though not given much thought, was a serious matter. In the majority of the plants which he had had occasion to examine in this regard he had found that the CO_2 percentage at the base of the stack ranged from 3 to 5 per cent. When the gases left the boiler the percentage was from 10 to 12, which meant a tremendous infiltration of air, in fact, so much so that the stack was burdened with 100 per cent more gas than it should carry away.

Others who briefly commented on the paper were Max Toltz,[7] who welcomed the new method as one that would make it possible to design stacks rapidly and with accuracy; and W. B. Frost, who believed that the new types of airtight flues would do away with much of the uncertainties in design caused by air infiltration.

(Continued on page 569)

[2] Ch. Engr., Green Engrg. Co., E. Chicago, Ind. Mem. A.S.M.E.
[3] Engr., Philadelphia Elec. Co., Philadelphia, Pa. Mem. A.S.M.E.
[4] Operating Engr., Philadelphia Elec. Co., Philadelphia, Pa. Mem. A.S.M.E.
[5] Prof. Mech. Eng., Johns Hopkins University, Baltimore, Md. Mem. A.S.M.E.
[6] Pres. & Combustion Engr., Uehling Instrument Co., Paterson, N. J. Mem. A.S.M.E.
[7] Mech. Engr., Toltz, King & Day, Inc., St. Paul, Minn. Past Vice-Pres., A.S.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Tables and Diagrams for Water Vapor Computed on the Basis of Its Specific Heat

By DR. OSCAR KNOBLAUCH, E. RAISCH, AND H. HAUSEN

EQUATIONS showing the variation of specific heat c_p with pressure and temperature have been available for many years, but all attempts to derive the general properties of steam from its specific heat by purely analytical means so as to cover by one general expression the wide range of conditions, have hitherto failed.

The present investigators claim to have derived an equation for the specific heat c_p of a simple character, with pressure and temperature entering as magnitudes of the first power only. Moreover, from the equation for c_p they have derived an equation of state as well as equations for entropy and heat content and have shown that the steam tables computed from the specific heat of steam with some auxiliary values are in good accord with tables derived by other means and values determined experimentally.

Equation for Specific Heat of Steam c_p

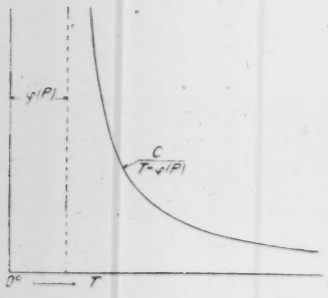


FIG. 1 GEOMETRICAL EXPRESSION FOR THE SECOND MEMBER ON THE RIGHT-HAND SIDE OF EQUATION [1]

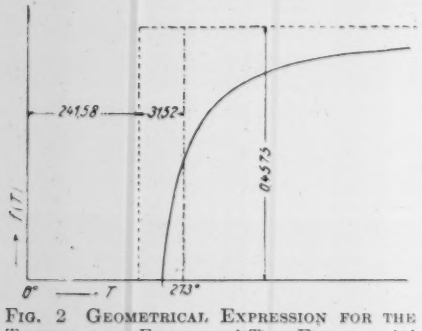


FIG. 2 GEOMETRICAL EXPRESSION FOR THE TEMPERATURE FUNCTION $f(T)$ IN EQUATION [1]

The present work is based on recent determinations of the specific heats of water vapor carried out by Knoblauch and Raisch at the Munich Technical High School. These values are given in a diagram in the original publication. In this the temperatures are plotted as abscissas and the c_p values as ordinates. Curves are then drawn through points thus obtained experimentally, connecting points of equal pressure (c_p isobars). It has been found that these c_p isobars are hyperbolic in their curvature, the position of the asymptotes varying with the pressure. This is expressed by the equation

$$c_p = f(T) + \frac{C}{T - \varphi(p)} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where $f(T)$ is a pure temperature function, $\varphi(p)$ a pure pressure function, and C a constant. A somewhat similar equation for c_p was proposed some years ago by R. Plank, but a pressure function was employed instead of the constant C and the temperature function was referred to the specific heat c_p at the pressure $p = 0$.

The selection of the functions involved and the constant C had to be made in such a manner that on the one hand Equation [1] would give for the specific heat c_p values agreeing with those obtained experimentally within the region from 0.5 to 20 atmos.; and on the other hand, would give also by extrapolation correct values for c_p at the critical pressure and at the pressure $p = 0$. In order to satisfy general thermodynamic requirements c_p must become equal to ∞ at the critical point, i.e., the critical temperature $t_k = 374$ deg. cent. and the critical pressure $p_k = 225.65$ atmos.

The constant C and the functions $f(T)$ and $\varphi(p)$ were determined first by trial and then by the method of least squares, this being done on the assumption that $T = 273.1 + t$. This gave

$$C = 20.33 \quad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

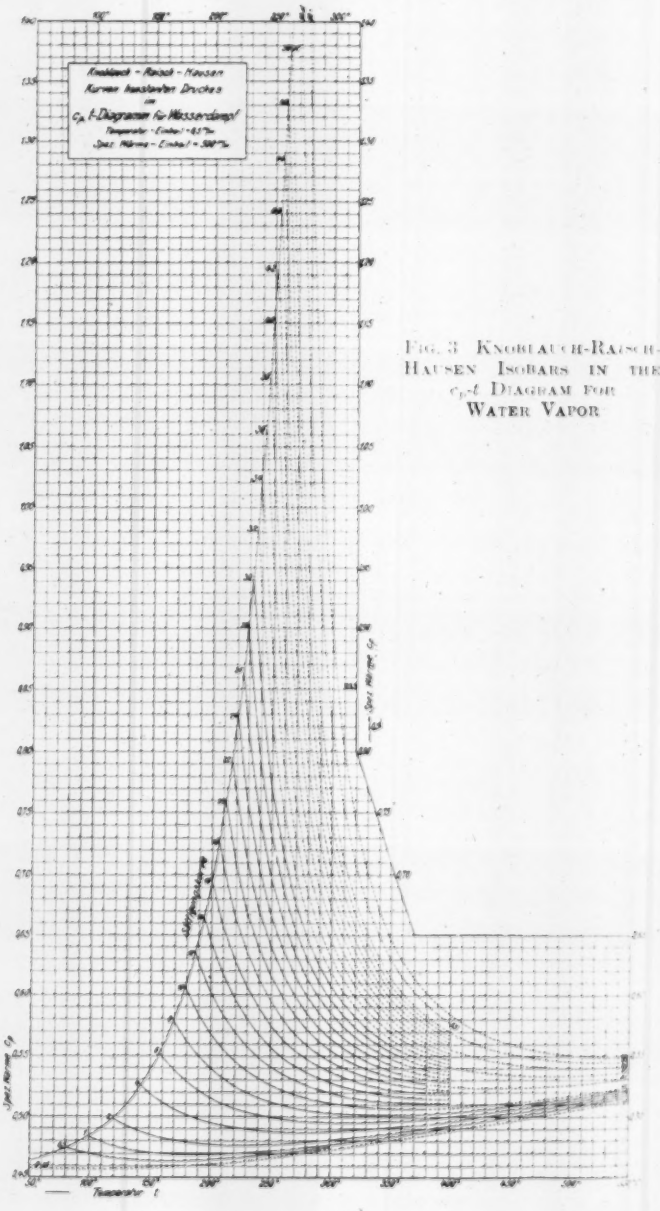


FIG. 3 KNOBLAUCH-RAISCH-HAUSEN ISOBARS IN THE c_p-t DIAGRAM FOR WATER VAPOR

$$\varphi(p) = 588.97 + 0.37354\,p - \frac{6310.3}{18.165 + p} \quad [3a]$$

with p expressed in kilograms per square centimeter, or

$$\varphi(P) = 588.97 + 0.37354\,[P \times 10^{-4}] - \frac{6310.3}{18.165 + [P \times 10^{-4}]} \quad [3b]$$

with P expressed in kilograms per square meter. For the region of temperature above 100 deg. cent. and also between 50 and 100 deg. cent.,

$$f(T) = 0.3391 + 0.000197T - \frac{12.8}{T - 256.4} \quad [4a]$$

and below 100 deg. cent.

$$f(T) = 0.4575 - \frac{20.33}{T - 241.58} \quad [4b][1]$$

If instead of absolute temperatures the temperatures in degrees centigrade be used, counting from the freezing point, Equations [4a] and [4b] read, respectively,

$$\text{Above 100 deg. cent.: } f(t) = 0.3929 + 0.000197\,t - \frac{12.8}{t + 16.7} \quad [5a]$$

$$\text{Below 100 deg. cent.: } f(t) = 0.4575 - \frac{20.33}{t + 31.52} \quad [5b]$$

Equation [1] for c_p after substituting the values given above for $f(T)$, $\varphi(p)$, and C will then read as follows:

For temperatures above 100 deg. cent.:

$$c_p = 0.3391 + 0.000197T - \frac{12.8}{T - 256.4} + \frac{20.33}{T - 588.97 - 0.37354p + \dfrac{6310.3}{18.165 + p}} \quad [6a]$$

or

$$c_p = 0.3929 + 0.000197t - \frac{12.8}{t + 16.7} + \frac{20.33}{t - 315.87 - 0.37354p + \dfrac{6310.3}{18.165 + p}} \quad [7a]$$

and for temperatures below 100 deg. cent.:

$$c_p = 0.4575 - \frac{20.33}{T - 241.58} + \frac{20.33}{T - 588.97 - 0.37354p + \dfrac{6310.3}{18.165 + p}} \quad [6b]$$

$$c_p = 0.4575 - \frac{20.33}{t + 31.52} + \frac{20.33}{t - 315.87 - 0.37354p + \dfrac{6310.3}{18.165 + p}} \quad [7b]$$

These equations give with great precision the values experimentally obtained by Knoblauch and Raisch for c_p. A valuable feature is that they contain pressure and temperature in the first power only, which permits the use of the slide rule in computations. In this connection it may be noted that Equation [1] admits of geometrical interpretation. Its second member $\frac{C}{T - \varphi(p)}$, when considered as a function of T, gives at constant $\varphi(p)$ an equilateral hyperbola, of which one asymptote is constituted by the axis of abscissas (axis of temperatures) and the other by a line parallel to the axis of ordinates and located therefrom at a distance $\varphi(p)$. For different pressures the distance $\varphi(p)$ varies, and therefore for various pressures we have a series of congruent equilateral hyperbolas differing from each other through being displaced in a horizontal direction.

The temperature function $f(T)$ may be likewise represented in accordance with Equation [4b] by an equilateral hyperbola, so that in accordance with Equation [1] the specific heat may be obtained by "additions" of hyperbolas.

From this expression for the specific heat of steam the authors proceed to derive various other equations. Because of lack of space it is impossible to give the derivations and only the equations themselves will be reproduced here.

Equation of State—Entropy and Heat-Content Equations

The equation of state is as follows:

$$v = \frac{RT}{P} - \frac{C\varphi'(P)}{A[\varphi(P)]^2}\left[T \log \frac{T}{T - \varphi(P)}\right] - \varphi(P) + \psi(P) \quad [8]$$

where

$$\psi(P) = -0.01151 + 0.0000257\,[P \times 10^{-4}] + \frac{0.438}{15.3 + [P \times 10^{-4}]} \quad [9]$$

It is of interest to note that the second and third members on the right-hand side of Equation [8] represent the deviation of steam from the ideal gas state.

[1] No explanation is given as to which of the two equations, ([4a] and [4b]), should be applied between 50 and 100 deg. cent.

TABLE 1 STEAM TABLE COMPUTED FROM TEMPERATURE

1 Temperature, deg. cent. t	2 Absolute temperature, deg. cent. T	3 Absolute saturation pressure, kg. per sq. cm. p_s	4 Specific volume of saturated steam, cu. m. per kg. v''	5 Specific weight of steam, kg. per cu.m. γ''	6 Heat content of liquid, kg.-cal. per kg. i'	7 Heat content of steam, kg.-cal. per kg. i''	8 Total heat of evaporation, kg.-cal. per kg. $r = i'' - i' = r'$	9 Sensible heat of evaporation, kg.-cal. per kg. $AP_s(v'' - v')$	10 Latent heat of evaporation, kg.-cal. per kg. $\rho = r - AP_s \times (v'' - v')$	11 Entropy of liquid, kg.-cal per deg. cent. per kg. s'	12 Entropy of steam, kg.-cal per deg. cent. per kg. s''	13 $s'' - s' = r/T$	14 Temperature, deg. cent. t
125	398.1	2.3670	0.77046	1.2979	125.5	648.6	523.1	42.66	480.4	0.3781	1.6926	1.3145	125
130	403.1	2.7549	0.66830	1.4963	130.6	650.2$_5$	519.6$_5$	43.06	476.6	0.3908$_5$	1.6803$_5$	1.2895	130
135	408.1	3.1915	0.58212	1.7179	135.7	651.8	516.1	43.44	472.7	0.4034$_5$	1.6684	1.2649$_5$	135
140	413.1	3.685	0.50857	1.9663	140.8$_5$	653.3$_5$	512.5	43.81	468.7	0.4159	1.6568	1.2409	140
145	418.1	4.238	0.44591	2.2426	146.0	654.8	508.8	44.16	464.6	0.4382$_5$	1.6454	1.2171$_5$	145

TABLE 2 STEAM TABLE COMPUTED FROM PRESSURE

1 Absolute pressure, kg. per sq. cm. (atmos.) p	2 Saturation temperature, deg. cent. T_s	3 Absolute temperature, deg. cent. T_s	4 Specific volume of saturated steam, cu.m. per kg. v''	5 Specific weight of saturated steam, kg. per cu.m. γ''	6 Heat content of liquid, kg.-cal. per kg. i'	7 Heat content of steam, kg.-cal. per kg. i''	8 Total heat of evaporation, kg.-cal. per kg. $r = i'' - i' = r'$	9 Sensible heat of evaporation, kg.-cal. per kg. $AP_s(v'' - v')$	10 Latent heat of evaporation, kg.-cal. per kg. $\rho = r - AP_s \times (v'' - v')$	11 Entropy of liquid, kg.-cal. per deg. cent. per kg. s'	12 Entropy of steam, kg.-cal. per deg. cent. per kg. s''	13 $s'' - s' = r/T_s$	14 Absolute pressure, kg. per sq. cm. (atmos.) p
2.0	119.61	392.71	0.90221	1.1084	120.0	646.9	526.9	42.26	484.6	0.3643	1.7062	1.3419	2.0
2.5	126.78	399.88	0.73201	1.3661	127.3	649.3	522.0	42.81	479.2	0.3827	1.6881	1.3054	2.5
3.0	132.87	405.97	0.61698	1.6208	133.5	651.2	517.7	43.28	474.4	0.3981	1.6735	1.2754	3.0
3.5	138.18	411.28	0.53375	1.8735	139.0	652.8	513.8	43.67	470.1	0.4114	1.6610	1.2496	3.5
4.0	142.91	416.01	0.47082	2.1240	143.8	654.2	510.4	44.01	466.4	0.4231	1.6501	1.2270	4.0
4.5	147.19	420.29	0.42159	2.3720	148.3	655.4	507.1	44.33	462.8	0.4336	1.6405	1.2069	4.5

The entropy equation is

$$s = s_0 + \int \frac{f(T)}{T} dT - \frac{C}{\varphi(P)} \log \frac{T}{T - \varphi(P)} - A R \log P \quad [10]$$

where s_0 has the average value of 0.73279.

The equation for the heat content is

$$i = i_0 + \int f(T) dT + C \log [T - \varphi(P)] + A \int \psi(P) dP \quad [11]$$

The notation for Equations [8] to [11] is as follows:

- t = temperature in deg. cent. counting from the freezing point
- T = absolute temperature in deg. cent. = 273.1 + t
- A = 1/426.9 = reciprocal of the mechanical equivalent of heat
- R = 47.10 = gas constant of water vapor
- u = internal energy in kg-cal. per kg.
- v_0, u_0, s_0 and i_0 = respectively, the specific volume, internal energy, entropy, and heat content at 0 deg. cent. and the corresponding saturation pressure $(p_s)_0$ = 0.006226 atmos.
- v', u', s' and i' = corresponding values for liquid water at temperature t_s corresponding to saturation pressure p_s
- v'', u'', s'' and i'' = corresponding values for dry saturated steam.

The original publication discusses in some detail the process as employed in making the theoretical calculations and presents a comparison of the steam tables computed from the values of the specific heat with the results of direct observation.

Conclusions Arrived at by the Authors

A comparison of the steam tables with thermodynamic deductions and results of observations leads the authors to the following conclusions:

1 It follows from theoretical considerations that for the critical state $c_p = \infty$; actually this value is obtained from Equation [1] for t_k = 374 deg. cent. and p_k = 225.05 atmos.

2 The heat content of water vapor at constant temperature decreases with increase of pressure. This is actually found to be the case in the i-s and i-p isotherm diagrams.

3 The following remarks are made in reference to the extent of further numerical control of steam tables. Equation [10], derived to express entropy s, contains in addition to the thermodynamically established relation between c_p, pressure, and temperature only the constant of integration s_0. In this equation, therefore, apart from this quantity s_0, the experimentally established behavior of the c_p values is expressed in its purest manner. This makes the computations carried out in connection with the values of entropy all the more valuable.

Now, if we connect by means of

$$(s'' - s')T_s = r \quad [12]$$

the values of s'' computed in accordance with Equation [10] with the experimentally determined values of s' and T_s, we obtain the heat of vaporization r. The authors give for purposes of comparison the values for r experimentally determined by Henning and in a parallel column those computed from the Clausius-Clapeyron equation. The differences between the two sets of values are very slight, however, which is particularly interesting in view of the fact that these two sets of values have been obtained in entirely different ways which are independent of each other.

The original publication contains steam tables computed from the specific heat. Of these only two are reproduced here on account of lack of space. (*Tabellen und Diagramme fur Wasserdampf berechnet aus der spezifischen Wärme*, Verlag R. Oldenbourg, Berlin, 1923, 32 pp., illustr. *et.A*)

An Investigation of Welded Pressure Vessels

AN EXTENSIVE PUBLICATION which may be divided into three parts, namely: a report of tests carried out by the Bureau of Standards; an analysis of test data given in this report and comments on the various features considered; and finally, recommendations made by the Pressure Vessel Committee of the American Bureau of Welding for the consideration of the Boiler Code Committee of The American Society of Mechanical Engineers in their revision of the Code for Unfired Pressure Vessels.

As regards the report of the Bureau of Standards, it deals with an investigation of strength of welded pressure vessels. As it is expected that it will be published by the Bureau in the usual manner, at which time it will be available at a very low cost to all those interested in the subject, only the conclusions arrived at are reported here. These are:

1 The double V-weld is much superior to the single V-weld.

2 The pipe shells tested were less uniform and averaged lower in strength than double V-welded plate shells.

3 The butt-welded heads were stronger than the inserted heads.

4 A hammer test cannot be relied upon to show more than a very few exceptionally defective welds.

5 The hammer test, as applied, apparently did not weaken the tanks.

6 Hydrostatic pressure 1½ times the working pressure showed only a small number of imperfected welds, even when the hammer was used.

7 Hydrostatic pressure sufficient to stress the shell to the yield point will show a large proportion of imperfect welds.

8 Hydrostatic pressure sufficient to produce a permanent set in the shell, enlarging the circumference ½ per cent, apparently does not weaken the tank.

9 Flanges for inspection plugs can be welded in the heads of a tank without weakening it.

The comments on the report of the Bureau of Standards fall into several sections. In those dealing with construction it is pointed out among other things that there is one principle which it is felt should be carried out in all welded steel structures of importance, which is that the included V-angle should not be less than 90 deg.

The shells in these tanks were crimped over the heads, a construction that is thought by many to give added strength. There is some doubt, however, as to its effectiveness, though this must increase as the diameter of the tank decreases, the thickness of the shell and the amount of crimping being the same. The drawing of these tanks submitted by their maker shows such an amount of crimping as to make the V-angle so small that it is quite impossible to make the weld as indicated. The photograph of the actual sections shows this to be true, and it seems clear that, considering the small amount of weld metal actually holding, and the fact that there is bad bending action in the weld, the very high factor of safety is all that saves the construction from failure, and so the design cannot be commended. It is believed that other designs, more efficient, and probably just as cheap, are available, and that they should be used in the interests of safety. Of course there can be no objection to the use of pipe for the shell with a proper factor of safety, and with flanged heads butt-welded to the shell the construction would be beyond criticism.

In one of the tanks tested, in fact, the strongest of the lot, it was found that there was a severe strain on the head weld caused by its rigidity which kept it from bending while the material on both sides of it could distort. In another instance one of the head welds cracked under the hammer test.

The maker reports that during the 50-lb. hydrostatic shop test for tightness there were found two damp spots, one in each head seam, which were rewelded, and after retest were found tight. It is not possible now to identify these spots, but the crack may be at one of them.

This rewelding might account for a local stress, which, added to the test stress, might be of sufficient amount to cause local rupture. It is a very good illustration of what may occur if enough care be not taken in making repairs.

There are three points to note in this connection:

1 The static test at 1½ times the working pressure did not detect the defect.

2 The defect was found by the hammer at a lower pressure than 1½ times the working pressure.

3 The crack was evidently caused by local internal stresses because (*a*) it occurred at low pressure and (*b*) it was local.

So far as this case is concerned, it seems clear that something more than a static test is needed, and that a shock of moderate amount while the tank is under moderate pressure will show up defects not revealed by a static pressure of the same or somewhat greater amount.

It is probably a good thing that this tank failed as it did, as it shows that the Code provision for a reweld and retest is safe practice if the work is properly done. It is also evident that local stresses can exist in otherwise properly welded tanks, and that they have no effect on the strength of the rest of the welds.

DESIGN

It is claimed that the best method for applying heads is by butt-welding a flanged head to the shell, and where a head convex to the pressure is used the method in the Code should be followed.

As regards the question of what fiber stress should be used in designing unfired pressure vessels, the conclusion is reached that it seems quite fair and safe to use 50,000 lb. as the basis for design. With a factor of safety of 5, and a weld value of 80 per cent, this would mean a design fiber stress at the working pressure of 8000 lb., based on the nominal plate thickness. In view of the high efficiency of the double V-weld, 97 per cent or 9700 lb. fiber stress, using the above basis, this does not seem to the Committee excessive, unfair, or in any degree dangerous, and they therefore recommend its adoption. It would apply also to the special tanks, only 4 of the 23 having less than 50,000 lb. tensile strength.

For wrought-iron pipe used for pressure vessels a maximum working fiber stress of 4000 lb. is recommended, although it is pointed out that steel pipe is just as easy to obtain and makes the construction safer.

The Committee considers it inconsistent to allow 150 lb. for air tanks and 250 lb. for ammonia tanks. It believes that it is entirely safe to put all liquids or gases on the same basis as far as welding is concerned.

The Committee also objects to the requirement in the Code to the effect that heads convex to the pressure shall have a skirt not less than 3 in. long. This is impractical for smaller-sized heads and the Committee recommends certain relations between the length of the skirt and the diameter of the head. Also the Committee believes that the constricting or crimping of the end of the shell is unnecessary, although not objectionable. The Committee also recommends a certain form of convex head. The necessity for this is due to the fact that as heads convex to the pressure are much thicker than the shell, the welder is at some disadvantage unless the head is reduced in thickness. There are a number of other recommendations which cannot be reported here on account of lack of space.

HYDROSTATIC HAMMER TEST

A search was made by one of the Committee, but only a few references have been found, and they are merely references to the fact that it is used.

The American Society for Testing Materials provides in its specification for cast-iron pipe as follows:

SECTION 14 The straight pipes shall be subjected to a proof by hydrostatic pressure, and if required by the engineer, they shall also be subjected to a hammer test under this pressure. [No details of how the test is to be applied are given.]

The pressure to which the different sizes and classes of pipes shall be subjected are as follows:

Class	Working pressure[1]	Test Pressure 20 in. diam. & larger	Test Pressure Less than 20 in.	Fiber stress at test pressure	Fiber stress at test pressure[2]
A	43 lb.	150 lb.	300 lb.	4 in., 1420 lb. 18 in., 4200 lb.	20 in., 2230 lb. 60 in., 3230 lb.
B	86 lb.	200 lb.	300 lb.		
C	130 lb.	250 lb.	300 lb.		
D	173 lb.	300 lb.	300 lb.	4 in., 1150 lb. 18 in., 2760 lb.	20 in., 2900 lb. 60 in., 3780 lb.

[1] Added to table. [2] Calculated from data in specifications.

It will be seen that the ratio of test pressure to working pressure varies widely—from about 7.0 to 1.7—and that the fiber stresses in the table are likewise irregular and variable. The Committee is not in a position to criticize, and simply points out the variations as indicative of either unusual conditions or of lack of standardization, probably the latter.

The data and wording of the American Water Works Association specifications are identical with those of the American Society for Testing Materials.

Statements are given of methods of hammer testing cast-iron and steel pipe. From both it will be seen that the hammer used is not heavy, and, from a study of the tables of test pressures, that the fiber stresses used are not as high as in the Bureau of Standards' tests. The test pressures in the proposed revision of the A.S.M.E. Rules for Piping and Fittings are the same as those of the American Society for Testing Materials, and no hammer test is specified in either case.

On the other hand, there are data in favor of this test. One of the members of the Boiler Code Committee, who is a strong advocate of the Code test, states that in his experience it has been of much value in detecting leaks and other imperfections.

One of the members of the present Committee, who has used the hammer test for several years, states that by employing it some leaks have been found that were not shown up by the pressure alone, and he would not want to omit its use.

It has been the experience of one job welding shop, in the case of many hundreds of cast-iron vessels, ranging in size from small auto cylinders to very large heating-boiler sections, that, with a city water pressure of from 40 to 60 lb., an ordinary machinist's hammer, used in proportion to the weight of the vessel, will invariably detect a strain due to uneven shrinkage, and that if no effect is produced by the hammering, there is also invariably successful service. It has also been their practice for over five years, in cases where the working pressure is known, to use the Code test on all welded cast-iron pressure vessels, such as steam-jacketed kettles, and they state that they would not feel safe in letting them leave the shop without being so tested, and that no vessel of this type passing this test has ever failed in service.

It is their belief that the test is specially adapted to detect strains, which are serious in cast-iron welds, and that it will not, from their experience, detect an imperfect cast-iron weld unless there is a strain in it, because the factor of safety in the vessels referred to is made very high because of foundry conditions, so that even an imperfect weld will be plenty strong enough.

The statement usually made, as far as the Committee knows, is that the Code test should detect a bad weld. At once the question may be asked, What is a bad weld? The Committee knows of no attempt to evaluate or define it. There are evidently various degrees of badness in welds, as in anything else, but in the tests no "bad" weld was detected by the Code test except one (Tank X15). The other one found by it was a good weld (Tank K4), containing a local strain, which was repaired and the tank on retest broke at 50,500 lb. fiber stress. It is quite probable that X15 had a strain in the weld, due to the thin welds having to stand all the shrinkage stress.

The Committee has inquired of its members and others as to their idea of a bad weld, which would be discovered by the Code test, and has found that none of those questioned had any definite opinion on the matter.

PHYSICAL QUALITIES OF MATERIALS

The Code has no specifications for the pipe which was used for nine of the regular tanks tested. The Committee feels that wrought-iron pipe being naturally weak longitudinally in the tank or transversely in the skelp, is not a suitable material for pressure vessels unless the factor of safety is very high, and that lap-welded steel pipe could be used instead without any hardship.

The subject of high- or low-tensile-strength plate for welding is discussed in some detail. As regards the yield point, it is believed to be perfectly safe to allow a high yield point, especially since the material is annealed by the welding for quite some distance from the weld. This annealing increases the elongation, allowing the steel to absorb the welding strains in spite of higher tensile strength than the Code allows. From the foregoing it is safe to provide

that material 1/4 in. thick or less shall have the following physical properties:

Tensile strength (T.S.), lb. per sq. in.	60,000 max.
Yield point, lb. per sq. in.	0.5 T.S. min.
Elongation, per cent in 8 in.	1,500,000/T.S.

provided that the elongation be measured on a gage length of 24 times the thickness and that the Code chemical analysis be complied with, and the Committee so recommends. The Committee believes that the use of a definite minimum for the yield point is not as good as the limit used in the Boiler Code in which the yield point is equal to 0.5 T.S. min., because the former excludes Armco iron, a very good material, while the latter admits it. Whatever form of specification is used, Armco iron should be allowed. Further, the Committee believes that if its recommendation as to hydrostatic test at three times the working pressure be adopted, the yield point minimum of 24,000 lb. is too low, as it is just three times the fiber stress, 8000 lb., of which the Committee is in favor.

Chemical Requirements of Plate

The Committee recommends the following as a specification that will fit all cases:

	Per cent max.		Per cent max.
Carbon	0.15	Phosphorus	0.04
Manganese	0.30 to 0.60	Sulphur	0.05

It is believed that there should be a low limit on the manganese, to insure good steel, and 0.30 per cent is recommended. This would exclude Armco iron, which is entirely suitable for pressure vessels, provided its low tensile strength (about 45,000 lb.) is allowed for, and its use should be permitted by some such wording as, "The use of ingot iron is permitted provided a fiber stress of 7200 lb. per sq. in. at the working pressure is not exceeded." (*Journal of the American Welding Society*, vol. 2, no. 5, May, 1923, pp. 11 to 162, 120 figs., *epA*)

Short Abstracts of the Month

AIR MACHINERY

Device for Testing Air Drills and Hammers. Description of an air-motor testing device which has recently been developed at the shops of the Pittsburgh & Lake Erie Railroad at McKees Rocks, Pa.

For testing drills a motor is mounted in the device and is guided at the drill by a cross-bar resting on a test block. Air is supplied to the cylinder through a flexible hose and valve. When the air is admitted at the top of the cylinder and exhausted at the bottom, this forces the piston down on top of the air motor at a pressure indicated by the gage, and the extent of this pressure may be regulated as desired.

For testing, the air motor is set up with a 2-in. drill point resting on the test block and pressure is applied slowly until the air motor is pulling to capacity. The revolutions per minute are counted and the pressure is noted. The pressure needed to stall the motor is also recorded and, provided the sharpness of the drill point is kept constant, this pressure is the measure of the efficiency of the air motor. Through this test one may determine whether or not a drill after being repaired has been brought back to its rated capacity.

In ascertaining the vibrations of hammers, the piston rod of the 8-in. by 14-in. air cylinder of the testing machine is chalked, and the vibrations are indicated by a pair of calipers held against the piston rod. The hammer is allowed to run for a given length of time and the vibrations are measured. This test is run to make comparisons between different types of new hammers, and it is also applied when old hammers are being overhauled, in order to find out if the vibrations have increased to any extent with the age of the pneumatic tools.

D. G. Redding, assistant superintendent of motive power of the Pittsburgh & Lake Erie Railroad, reports that some of the hammers which were said to have the least vibration have shown excessive vibration under this kind of test. He is considering modifying the machine in question in such a way that comparative capacity tests of hammers may be made with it. It is believed that this can readily be done by the aid of additional attachments. (*Compressed Air Magazine*, vol. 28, no. 7, July, 1923, p. 560, 3 figs., *d*)

BUREAU OF STANDARDS (See Refrigeration)

ENGINEERING MATERIALS

Corrosion of Condenser Tubes—Flow of Water and Air-Bubble Action

The Rapid Corrosion of Condenser Tubes, Guy D. Bengough and R. May. A brief summary of conclusions as to the cause of the rapid corrosion of condenser tubes which have been arrived at in the course of an investigation carried out during the last few years under the direction of the Corrosion Research Committee of the Institute of Metals. The full evidence has not yet been published.

The present article deals only with corrosion caused by the presence of entangled air in the circulating water in estuarine and marine conditions. The attack is especially serious, because it can cause tube failure in a few weeks or even days.

This cause is largely independent of the chemical composition of the tube, i.e., any ordinary tubes of commerce of 70 : 30 brass, Admiralty alloy, lead brass, or arsenical copper will show the action when exposed to suitable conditions. In fact, any selected area of any ordinary tube is liable, and can be made, to show the action. Certain alloys very high in nickel, e.g., containing up to 20 per cent nickel, fail as badly as brasses.

The action which produces the rapid failure has certain characteristics, of which the following is a list:

1 It usually occurs near the water inlet of the tubes in the first pass, and less frequently near the water outlet of long tubes.

2 It occurs indifferently anywhere round the circumference of the tube, and frequently all round it. A considerable area of tube is attacked, i.e., the action is not concentrated at sharply defined isolated pits.

3 A longitudinal section of a tube corroded by this action when rubbed down on an oil stone shows a characteristic "water worn" appearance, from which the direction of the flow of the water can be readily determined.

4 The tubes showing the action are often found to be spaced over a comparatively small area of the tube plate. If a corroded tube be replaced by a new tube, the latter will often again fail rapidly, and the process may be repeated several times.

5 The action is seldom shown by tubes that have been a long time in the condenser, i.e., tubes either show it in their early life or not at all.

6 Ordinary methods of electrolytic protection fail to prevent the action.

7 Metallic copper is seldom found as a corrosion product at the corroded areas; these often seem remarkably free from corrosion products.

8 Ferrules occasionally show the action. These are frequently made of 60:40 alloy, but even in such cases it often happens that no metallic copper is visible at the corroded surface.

As regards the cause of corrosion, evidence seems to indicate that the main cause of the action must be in the conditions to which the tubes are subjected. Furthermore, it has been found that not all the tubes in a single pass are always in similar conditions and behave similarly if of uniform quality. This is due to the fact that the speed at the tube wall may vary in different tubes, as has been found by the use of glass tubes.

The phenomena of flow observed in the tubes varied considerably with the type of water used in the experiments. The behavior of sea water only will be discussed in the present article. The first point of importance to be noted is that smooth flow, such as is usually assumed to take place through all condenser tubes, did not take place through many of the tubes. In certain tubes the water stream formed vortices or more or less flat or extended spirals, especially for the first 2 ft. or 3 ft. of the tube. See Figs. 3 and 4. Where these spirals impinged on the walls local turbulence

was set up as shown in Fig. 4. Some approximate measurements were made—by a photographic method—on the variations of speed that occurred at various parts of the tube. For this purpose the introduction of small solid particles of air bubbles was useful; the behavior of these showed clearly that great variations of speed could take place even in a single tube. Thus at certain parts of a tube through which water was traveling at an average speed of 6 ft. per sec., local retardation near the tube wall might reduce the speed almost to zero, while in the center of the tube the speed might approximate to twice the average speed. Turbulence prevailed in different degrees in many of the tubes for a length of 2 ft. or 3 ft. from the inlet end and then gradually died away. When turbulence prevailed high water speeds might be attained locally near the tube wall. The actual amount of water passing through a given tube was, of course, greatest in the tubes with least turbulence, i.e., with the nearest approach to smooth flow. Probably the highest speeds were developed locally in tubes with the greatest turbulence. The phenomena differed noticeably in tubes in different positions relative to the main water inlet. Some tubes showed scarcely any vortices but local impingement on the tube wall near the inlet end—as shown in Fig. 2.

An increase in the water speed increased the complexity of the phenomena; a decrease to 2 ft. or 3 ft. per sec. caused an approximation to smooth flow to take place throughout the greater part of the tube.

TABLE 1 CORROSION OF BRASS TUBES (18 W.G.)

(Duration of experiment, 28 days; temperature, 20 deg. cent.; speed of water, 10 ft. per sec.)

Alloy	Per cent penetration on 1.21 mm. = 18 W.G.	Amount of entangled air in cc. per hr.
70-30	Less than 1	0.7
70-29-1[1]	2.5	0.7
70-30	Less than 1	25
70-30	Less than 1	145
70-30	31	3,000
70-29-1	35	3,000
70-30	83	11,000

[1] Laboratory-cast specimen.

It has previously been found experimentally that an increase in water speed, at least up to about 20 ft. per sec., increases the rate of corrosion of both copper and brass; consequently, the greatest local corrosion would be expected where the greatest turbulence prevailed, i.e., near the inlet end.

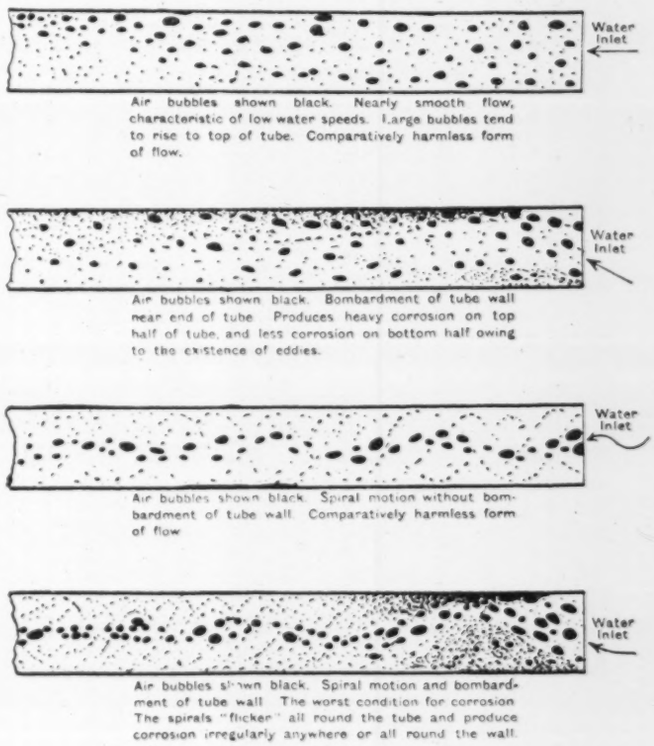
Nevertheless the failure of tubes in practice in a few weeks could not be explained on the basis of high water speed alone. Even with the highest water speed used in the experiments, namely, 25 ft. per sec., a copper tube would have a life of at least six months, at laboratory temperatures.

Further tests indicated that entangled air in water is the real cause of rapid corrosion. Sea water was found always to contain a small amount of air in very fine bubbles. These were evidently due to a certain amount of churning in the centrifugal pump which had caused them to pass out of solution. They retain their identity for considerable periods in this particular water for the same reasons which cause it to exhibit the familiar property of foaming, which is not possessed by many fresh waters.

Further, some comparative tests were made in which the corrosive effect of sea water containing only dissolved air in normal amounts was compared with that of the same water containing, in addition, mechanically entangled air. The results were very striking, and a few are shown in Table 1. In the case of brass condenser tubes the rate of corrosion is greatly increased when a certain small volume of entangled air is exceeded; thus with 3 liters of air per hour passing through the tubes their lives would be only about three months. These tests were carried out by impinging a jet of sea water containing air on to the surface of the tube arranged at right angles to it.

The total volume of air, however, is not the only factor in the case; another important one is its state of subdivision. A given volume of air is more harmful in a fine state of subdivision than when present in large bubbles. A fine foam appears to be the worst possible case. A foam consists of an intimate mixture of air and water, from which the air does not readily separate.

Very small amounts of certain liquids and solids can greatly stabilize foams, that is, prevent the separation of the air, e.g., certain oils and basic salts. Notable differences in the tendency to foam have been encountered between the samples of sea water collected in large stoneware jars and successively filled from the same position on a jetty; such differences may have a noticeable effect on corrosion. As a rough generalization it may be said, however, that the penetration of a tube per month by an air-sea-water jet containing three liters of air per hour in the conditions of Table 1 varies from 26 per cent to 33 per cent for the ordinary run of 70:30 tubes of commerce. With a highly foaming batch of water higher penetrations are occasionally observed, the highest yet recorded being 49 per cent. These experiments were usually carried out with sets of twelve tubes at a time, and it was clear that the varying results were due to the conditions rather than to the tubes, since if one tube gave a high result all the others in that set did so. In all cases the type of corrosion strikingly resembled that which occurs in conditions of ordinary practice.


Water Inlet
Air bubbles shown black. Nearly smooth flow, characteristic of low water speeds. Large bubbles tend to rise to top of tube. Comparatively harmless form of flow.
Water Inlet
Air bubbles shown black. Bombardment of tube wall near end of tube. Produces heavy corrosion on top half of tube, and less corrosion on bottom half owing to the existence of eddies.
Water Inlet
Air bubbles shown black. Spiral motion without bombardment of tube wall. Comparatively harmless form of flow
Water Inlet
Air bubbles shown black. Spiral motion and bombardment of tube wall. The worst condition for corrosion. The spirals "flicker" all round the tube and produce corrosion irregularly anywhere or all round the wall.

FIGS. 1 TO 4 BEHAVIOR OF WATER CONTAINING ENTANGLED AIR IN GLASS CONDENSER TUBES

A small amount of sulphuretted hydrogen in the water, such as is occasionally found in conditions of practice, greatly enhances the rate of attack; thus, with sea water containing 3 cc. of the gas per liter, penetrations of 82 per cent and 90 per cent per month of twenty-eight days have been recorded in the conditions of Table 1.

The reason for the peculiar distribution of the corrosion on tubes suffering from the rapid type of action described at the beginning of this article may now be suggested. It will be remembered that the position at which the action is usually worst is the first two or three feet of the tube at the inlet end. It is just at this position that turbulence and impingement of air on the tube wall are worst; here the tube suffers from an intermittent bombardment with air bubbles, as shown diagrammatically in Figs. 2 and 4. Further along the tube the turbulence dies out and corrosion falls off. The remarkable observation has been made, however, that the size of the bubbles gradually decreases, and toward the end of a long tube, i.e., 15 ft., much of the air appears to be distributed as a fine "mist" of air in water; i.e., in just the state in which it is most harmful. So fine is this mist that with an average speed of 7.5 ft. per sec. through the tube no tendency for the bubbles to rise to the top of the tube could be seen. Any roughening of the tube surface by local scale accumulation or otherwise, or any obstruction in the tube will be liable to cause local eddies and local air bombardment, and consequently give a chance for corrosion to start.

A simple method of reducing the trouble is suggested, namely, to use for replacements Admiralty tubes that have been heated to 40 deg. cent. for a week in sea water, which should be stagnant

or only slowly moving. If this cannot be done, then tubes from other parts of the condenser in which failures are known to be few should be used for replacements, and new tubes inserted in the positions thus vacated. This procedure will often require tubes to be moved from the second pass to the first in two-pass condensers, and will be most effective if proper records of failure are kept. (*The Engineer*, vol. 136, no. 3523, July 6, 1923, pp. 7–10, 15 figs., *eA*)

REPORT ON RESEARCHES ON THE CHEMICAL AND PHYSICAL PROPERTIES OF INSULATING OILS. The Research on Insulating Oils was initiated by the Institution of Electrical Engineers, continued by the Electrical Research Committee, and transferred to the British Electrical and Allied Industries Research Association.

The subject has been growing in importance in view of the increasing size and greater demand put upon transformers and oil switches, and would appear never to have received the thorough investigation it deserved. The results of the research should be of considerable assistance to designers and users of transformers and oil switches.

The sludging test is the most important test of the series. The prime object of the research on sludging was to ascertain by a series of tests carried out by different laboratories upon one and the same set of oils and using a selected method of test, whether a sludging test was suitable for standardization purposes in preparing purchasing specifications for insulating oils. This includes the question of rapidity, ease of performance, concordance of results between duplicate tests and between different experimenters; also the degree of accuracy to which the determination can be performed and the discovery of any possible improvement in the method itself.

Among other things it was concluded that driers containing lead or cobalt, or manganese resinates or acetates, are liable to increase the quantity of sludge formed by an oil. For this reason the use of paints or varnishes containing these driers should be reduced to a minimum if employed at all.

The article is of interest not only in view of the results obtained but also because of the description of the methods used for the various tests, such as determination of viscosity of oils, specific heat, latent heat of evaporation, vapor pressures, action of catalyzers, etc. (*The Journal of the Institution of Electrical Engineers*, vol. 61, no. 319, June, 1923, pp. 661–674, 6 figs., *e*)

Cement in Sea Water

THE DISINTEGRATION OF CEMENT IN SEA WATER, Wm. G. Atwood and A. A. Johnson. This paper is of interest as it gives in addition to engineering considerations the history and literature of the subject.

Among other things is discussed the so-called "ciment fondu," or cast cement, recently developed in France, the particular feature of which is the presence of alumina. This cement was widely used during the world war for the construction of gun platforms and the like where its quick-hardening qualities were of great value. One of the disadvantages of this cement is its cost, which is about double that of portland cement.

The authors arrive at the following conclusions:

1 Practically all skilled experimenters with hydraulic binding agents for the last 100 years have agreed that the primary cause for the disintegration of mortar and concrete in sulphate-carrying waters such as sea water and many alkali waters is the attack on the free lime in the mortar by the sulphates of the water.

2 The majority of the authorities agree that this disintegration can be prevented by the addition to standard portland cement of a properly constituted siliceous material which, by combination with the free lime released in the process of setting, will form a cementing material insoluble in sulphate-bearing water.

3 The high-alumina cements attain the same results by different means which appear to be just as effective. Thus far the cost of the high-alumina cements seems to be greater than that of portland, whereas the addition of silica to portland should result in a cheaper product. Considering the greater strength of the alumina cements, it is possible that the cost per unit (1 lb. per sq. in.) of strength may not be very different.

4 The use of a single standard specification for the binding agent in all structures, whatever the service conditions, does not seem to be desirable or efficient.

The purpose of the writers in collecting the information presented was to develop for their own use the necessary data for planning a comprehensive system of tests, which it is hoped may be conducted under the direction of the Committee on Marine Piling Investigations of the National Research Council. These tests, in their opinion, should be planned with consideration of the following points:

a In view of the great volume of previous research work and the general agreement in the results obtained, it seems unnecessary to make further tests to determine the causes of the failure of concrete in sulphate-bearing waters, particularly in view of the comprehensive study now being made at the University of Saskatchewan under the auspices of the Engineering Institute and the Research Council of Canada.

b Properly planned accelerated laboratory tests will give correct information as to the durability of the various binding agents within a comparatively short time. These tests should be checked by service tests which will require many years, but there seems to be no question as to the correctness of laboratory results.

c Thorough tests should be made of standard American portland cements strengthened by the addition of siliceous materials. These tests should be for the purpose of determining the necessary qualities to be possessed by the silica; proper proportions for the mixture with cements of various compositions, and the development of the most efficient and practicable methods of mixing.

d Similar tests should be made of the high-alumina cements. In this case the method of manufacture seems to be of the greatest importance. The most desirable chemical composition of the limestone and bauxite to be used for the manufacture of this type of cement should be determined more definitely than it has been.

The writers realize that many causes contribute to the failures of structures in sulphate-bearing waters and that much work has been done which has resulted in a longer life for these structures. They do not believe that the improvements resulting from previous experiments on methods of construction have solved the difficulty, nor that it will be solved until a cement immune from attack by sulphate-bearing waters is developed. (*Engineering World*, vol. 23, no. 1, July, 1923, pp. 25–31, 2 figs., *ph*)

FUELS AND FIRING

Melting Point of Coal Ash

THE MELTING POINT OF COAL ASH, F. S. Sinnatt, A. B. Owles, and N. Simpkin. This paper gives the literature of the subject and describes an apparatus for determination of the melting point of coal ash.

The melting point of the ash from vitrain, durain, clarain, and fusain from certain seams has been determined.

The melting point of the ash from different horizons in a seam is shown to vary within wide limits.

Different commercial grades of coal from the same seam may yield ashes, the melting points of which differ.

Certain bands in a seam may yield ash of very high melting point.

Chemical analysis is of little value as a criterion of the melting point of an ash.

Table 2 shows the melting point of the ash from certain commercial varieties quoted to indicate the order of the differences to be expected. It must be recognized that the slack and fine coal may not always yield ashes, the melting points of which are lower than the melting point of the ash from the lump coal from the same seam. Furthermore, the variations met with in the different grades are influenced to a large extent by the mode of occurrence of what may be called the "fortuitous" inorganic matter, and by the method of purification through which the coal passes prior to placing it on the market.

In Table 2 the slack and slurry are "washed coals." In all the other experiments the coal was unwashed.

TABLE 2 MELTING POINT OF COAL ASH IN DEG. CENT.

Seam	A	B	C
Grade of coal:			
Lump	1345	1280	1345
Slack	1240	1240	1300
Slurry	1190	1200	1180

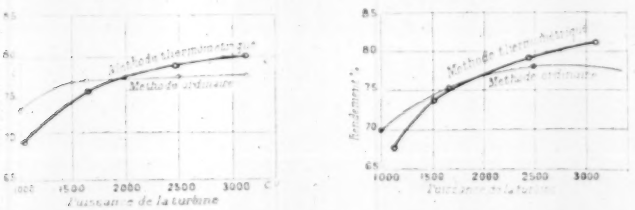
(Paper read before the Manchester Section of the Society of Chemical Industry and abstracted through the *Journal of the Society of Chemical Industry, Chemistry and Industry*, vol. 42, no. 25, June 22, 1923, pp. 266T–271T together with discussion 271–272T, 3 figs., *ep*)

HYDRAULIC ENGINEERING

Determining Efficiency of Hydraulic Turbines from Temperature Differences of Water

CALORIMETRIC METHOD FOR DETERMINING THE EFFICIENCY OF HYDRAULIC TURBINES. Barbillion and Poirson have recently developed a novel calorimetric method for determining the efficiency of hydraulic turbines that is remarkable for its simplicity, consisting as it does in merely measuring the difference in temperature of the water entering and leaving the turbine and the head employed.

Assume that a hydraulic turbine working at a given rate is supplied with Q liters of water per sec. falling from a height of H meters as read on a manometer. The power delivered to the turbine will then be $P = QH$ kg-m. per sec.



FIGS. 5 AND 6 TESTS OF TURBINES NO. 1 (LEFT) AND NO. 2 (RIGHT) OF THE FULLY PLANT BY THE THERMOMETRIC AND ORDINARY METHODS

(*Rendement* = efficiency; *puissance de la turbine* = turbine output; *méthode thermométrique* = thermometric method; *méthode ordinaire* = ordinary method.)

Assuming that the various losses of energy in this turbine are all totally converted into heat and that the latter is carried off by the water itself, the heating of the water, which is the difference between the temperature Θ_1 at the entry to and the temperature Θ_2 at the discharge from the turbine, will then be proportional to the losses p, which can be written as

$$p = 427\ Q\ (\Theta_2 - \Theta_1) \text{ kg-m. per sec.}$$

The efficiency is then

$$\eta = \frac{P - p}{P} = \frac{QH - 427Q(\Theta_2 - \Theta_1)}{QH}$$

or

$$\eta = \frac{H - 427(\Theta_2 - \Theta_1)}{H} = 1 - \frac{427(\Theta_2 - \Theta_1)}{H} \text{ kg-m. per sec.}$$

This equation is notable from the fact that the discharge Q, which is the magnitude most difficult to measure, is entirely eliminated and the value of the efficiency can be obtained instantly by reading the difference of temperatures and the manometric pressure.

On the other hand, the thermometers must be simple and capable of reading temperature differences of the order of $^1/_{10}$th of a degree centigrade. There are today, however, thermoelectric devices which permit reading such temperatures with certainty.

Some have questioned the accuracy of this method on the ground that there might be other causes that would bring about differences of temperature. In this connection Figs. 5 and 6 are of interest, as they show the results obtained by the ordinary method and by the thermometric method in tests on two turbines of the Fully plant functioning with the highest head in the world. The two methods appear to give fairly close results at very large outputs, and at outputs in the neighborhood of 1800 to 1900 hp. the results coincide.

The calorimetric method is of particular value in cases where it is desired not so much to determine the actual efficiency of a plant as to control variations of efficiency, for which latter purpose it provides a simple means. (*Le Génie Civil*, vol. 82, no. 25, June 23, 1923, pp. 604–605, 2 figs., *de*)

INTERNAL-COMBUSTION ENGINEERING

Bethlehem Diesel Engine and Lowe Burner—Application to Motor Vehicles

THE NEW BETHLEHEM DIESEL ENGINE. Description of two forms of a new type of Diesel engine now under construction at the Potrero Works of the Union Plant of the Bethlehem Shipbuilding Corporation (Pacific Coast).

Two engines of the three-cylinder 150-hp. type are being built for use in the company's power plant where they will be put through a series of tests. A single-cylinder engine of this design has been running on the test stand at the Potrero Works for about three months, including a 14-day non-stop run on full load. The particular feature of this engine is the low-pressure system of oil burning without outside artificial aid in ignition. This is accomplished through the Lowe burner, for which the Bethlehem Shipbuilding Corporation has purchased the manufacturing rights.

This burner consists of a simple check valve in combination with an oil-burning tip. The tip is located in a recess in the cylinder head and surrounded by a double sleeve valve of thin polished steel, so shaped and positioned that all radiant heat which may be contained in the inner steel shell is focused on the minute drop of oil at the burner tip. The stored heat of compression in the cylinder, and the heat of combustion of the fuel oil itself added to the heat of compression, insure ignition at the moment of injection of the oil. The single-cylinder test engine referred to above was operated at compression pressures around 250 lb. Its cylinder stroke and bore are 12 in. and 8 in., respectively, and on all of its tests under all conditions of load the engine is said to have never missed a shot after starting.

The mechanical design of the engine is for two-cycle combustion, and in the experimental engine a scavenging air pressure of about $3^1/_2$ lb. was provided by crankcase compression. In the three-cylinder unit an extra cylinder is installed for scavenging air.

One feature of the Lowe system of burning oil in the engine cylinders of the two-cycle type is the by-passing of a part of the scavenging air from the scavenging-air manifold to the top of each cylinder, where this air is induced through a small check valve. This method of handling the scavenging air seems to aid in keeping the engine cool under running conditions. The test engine at the Potrero Works shows an exhaust temperature never exceeding 260 deg. fahr. A comparatively small amount of circulating water is used and the water seldom rises higher than 140 deg. at the outlet.

Certain features are of interest. Thus, the only fit between the cylinder head and the cylinder is between the shoulder on the head and the cylinder bore where a small, light copper gasket is squeezed in between the chamber on the bore and the 45-deg.-angle corner of the shoulder. There is no opening in the castings for water circulation from the cylinder walls to the head. Water circulation between these two is arranged on the outside by a simple pipe connection.

Control of the firing of cylinders is arranged entirely through the fuel pump. The fuel pump is operated by means of an adjustable block link actuated by a rolling-contact lever, which in turn is actuated by a camshaft. Through a spiral slot on this camshaft it is possible by manual control to twist the cams 180 deg. and reverse the engine. Through a manual adjustment of the block in the link any number of variations in the stroke of the fuel pump from zero to maximum can be easily obtained. This block is under control by compact form of centrifugal governor, and satisfactory regulation of the speed of the test unit has been obtained.

The engine is very light, the heavy-duty type weighing approximately 106 lb. per shaft hp. This brings it close to the range of automobile-engine design. In fact, the original article shows a four-cylinder two-cycle 50-hp. motor expressly designed for installation on a five-ton truck. This engine is now under construction at the Potrero Works. The compression pressure will be from 200 to 250 lb. with the engine running at 1200 r.p.m. The bore and stroke are 4 in. and 7 in., respectively. The minuteness of the quantity of oil used on each stroke of the engine is indicated by the dimensions of the pump, in which the plungers are $^1/_2$ in. in diameter and have a maximum stroke of $^1/_8$ in. Careful design has been necessary in laying out the link diagrams for the control mechanism, so as to give positive control of the pump-plunger

actuating links. The entire speed control of the engine is from foot or hand throttle adjustment of the block on a modified Stephenson link actuated through rolling-contact levers worked by the camshaft. (*Western Machinery World*, vol. 14, no. 7, July, 1923, pp. 215–217, 3 figs., *d*)

LUBRICATION (See Engineering Materials)

POWER-PLANT ENGINEERING (See also Engineering Materials, Railroad Engineering)

LaBelle's Giant Uniflows. Data and description of two engines now under construction at the LaBelle plant of the Wheeling Steel Corporation. These engines are of the reversing type with Marshall link and will use steam at 220 lb. pressure and 150 deg. superheat. One of them is to drive the 40-in. blooming mill now building. The other engine, with flywheel addition, will drive the 19-in. continuous mill. Each engine has four cylinders 36 in. by 60 in. and at 75 r.p.m. will develop 13,000 hp. (*The Blast Furnace and Steel Plant*, vol. 11, no. 6, June, 1923, p. 303, 1 fig., *d*)

Machinery for Mixing Fuel Automatically. Description of an installation at the coaling station at South Junction near Plattsburg, N. Y., of the Delaware & Hudson Railroad, where the mixing of mine-run bituminous coal with pea anthracite coal is effected with simple equipment.

The operations of receiving the coal in the track hopper, the feeding of uniform charges into an elevating bucket, and the delivery of the bucket to the point of dumping over the top of the storage bin have remained the same as before. The only change has been to provide two track hoppers, one for receiving the anthracite coal and the other for the bituminous coal, Shraeder automatic measuring feeders, by means of which the coal is delivered to the elevating bucket, being made to serve as the proportioning devices for mixing the coal. The bucket itself is utilized as a receptacle for the receipt of the mixture from the two feeders.

To provide means of varying the proportions, two Shraeder measuring feeders were equipped with diaphragms or vanes made to swing out from one of the walls so as to cut off a portion of the volume of the chamber and thus change the amount of coal of one kind or another being delivered to the elevating bucket. The position of this diaphragm is controlled by a screw provided with suitable calibrations so that the proportions of the mixture may be controlled at will. The operation does not vary from the usual arrangement. The elevating bucket, which has a capacity of three tons, descends between the two track hoppers and in so doing opens the two measuring feeders, causing the two grades of coal to flow from each side at the same instant and effect a thorough mixture.

The plant operates at the rate of 75 tons per hr., performing the operations of both mixing and crushing. The proportions of the mixing can be modified from a ratio of 65 per cent bituminous coal and 35 per cent anthracite to a ratio of 25 per cent bituminous and 75 per cent anthracite. The plant is equipped with a Roberts & Schaefer direct-connected spur-gear-driven electric hoist connected to a 25-hp. General Electric motor equipped with solenoid brakes. A Cutler-Hammer automatic controller provides for the continuous ascent and descent of the elevating bucket, push-button control being provided both at the top of the pocket and in the hoist house for the stopping and starting of the motor. (*Railway Age*, vol. 74, no. 29, June 23, 1923, pp. 1533–1534, 4 figs., *d*)

Power and Process Steam in a Cotton-Goods Finishing Plant, Alfred Iddles. Description of an installation in a cotton-goods bleaching, dyeing, printing, and finishing plant which includes a combination of non-condensing and bleeder-type turbines.

The finishing of cotton goods requires a large amount of power and heat. In New England the power can frequently be obtained from the rivers, but heat has to be generated by fuel. The power load does not parallel the needs for heat, so that there is frequently much waste of heat. The variation in heat requirements due to changing process needs and seasonal heating demands and the fluctuation in power obtainable from the rivers make it necessary to have a very flexible power- and heat-generating plant if the maximum economy is desired.

The present article describes the way in which this problem was met in the Norwich, Conn., plant of the U. S. Finishing Co. Careful analysis of operating conditions had shown that a combination consisting of two non-condensing turbines and one bleeder-type turbine could be operated with sufficient flexibility to care for the variable electrical load and at the same time produce no more than sufficient exhaust steam for the requirements of the mill. By the addition of an extra governor valve and proper arrangement of the turbine, it was found that the bleeder type could be converted into a bleeder and mixed-pressure type. Such a combination was desirable in order that the sudden fluctuation between the electrical load and the exhaust-steam requirements could be taken care of automatically.

The installation as finally chosen consists of

1 Two 750-kw. non-condensing geared turbo-generator sets operating between 175 lb. and 15 lb. gage pressure.

2 One 750-kw. bleeder mixed-pressure geared turbo-generator operating with 175 lb. pressure at the throttle, bleeding at 15 lb. pressure, and the exhaust from the last stages going to a surface condenser at 28 in. of vacuum.

A drawing in the original article shows the piping system which was installed for distribution of live steam to the turbines and to the mill for processes which require pressures higher than 15 lb.

An interesting feature of this plant is the installation of steam flow meters in an effort to account for all the steam produced. There are both recording instruments which are located in the power plant and on the gage board, and integrating and recording meters located in the master mechanic's office in the mill.

The original article describes in detail the various features of the installation including the operation of turbine units. (*Textile World*, vol. 64, no. 1, July 7, 1923, pp. 83–91, 13 figs., *d,A*)

RAILROAD ENGINEERING

Conical-Bottom Tanks in Water-Softening Plants

New Features in Water-Softening Plants, C. R. Knowles. Description of a type of water-softening plant adopted by the Illinois Central for twelve units to be used between Clinton, Ill., and Omaha, Neb. These plants are all of the continuous type and represent a new design in the construction of the tanks and housings.

The treating-plant houses are of a uniform design and are built in two sizes, 20 ft. by 40 ft. and 20 ft. by 60 ft., depending upon the capacity of the plant and the amount of storage space required. A space of 20 ft. by 20 ft. is reserved for the chemical equipment, filters, etc., and the remainder is used for storage of chemicals, the smaller house having storage space for two cars of chemicals and the larger house for four cars. That portion of the house reserved for the equipment has a 12-ft. ceiling to allow the necessary headroom for tanks, shafting, etc., while the storage room has a 10-ft. ceiling, as it is impractical to pile the chemicals in storage higher than 8 ft.

This type of structure increases the cost of the building slightly but adds materially to its appearance and convenience and is a pleasing departure from the barnlike appearance of many of the treating-plant houses formerly constructed.

The outstanding feature of these new plants is the conical-bottom tank which is a radical departure from the commonly accepted practice of building flat-bottom steel tanks of the standpipe type resting upon a concrete ring filled with broken stone or elevated wood tanks of similar design. A great deal of attention was given to the tank in designing these softening plants, and the conclusions reached, which have been borne out in practice, may be of interest.

Some authorities on water softening maintain that the movement of the water after leaving the downcomer is at an angle of 40 to 60 deg. upward and outward toward the walls of the tank, and that the water in the angle formed by the bottom and walls of the tank may be classified as dead water and should not be considered in figuring the available reaction time. This is undoubtedly true to a great extent, depending, of course, upon the relative temperatures of the incoming water and of the water of the tank. If the temperature of the incoming water is higher than that of the water in the tank, the movement as it leaves the downcomer will naturally be upward and as the temperature is equalized by contact with the water in the tank, it will probably spread toward the outside of the tank at an angle from the downcomer. On the other

hand, if the temperature of the incoming water is lower than that of the water within the tank, the movement will be along the bottom of the tank and the dead water will be displaced until the temperature of the water is equalized. This is of first importance in the selection of the type of tank to be used in the treatment of well waters.

The principal advantage of the conical-bottom tank in water softening is found to be in the collection and removal of the sludge and the resultant saving in water used for sludging over the flat-bottom tank. This feature alone will pay a good return on the cost of the tank. In the flat-bottom tank the sludge is distributed over the entire bottom of the tank and its removal necessitates the construction of an expensive sludge-collecting system, usually consisting of pipe with openings placed at intervals over the bottom of the tank, the most efficient of which are so arranged that the system may be operated in sections with from two to four sludge valves for each tank. Another type of sludge system is so constructed that the collecting pipes may be rotated over the bottom of the tank. None of these systems has been found entirely satisfactory, however, as they will not completely remove the sludge and are wasteful of water, as the sludge nearest the outlet is the first to be picked up and from two-thirds to three-fourths of the openings are discharging clear water long before the sludge near the outer edge of the tank is disturbed.

The sludge falls to the bottom of the conical-bottom tank and accumulates in the mud drum or riser where it is easily removed through a single opening and with a minimum waste of water. Actual tests to determine the amount of water in removing sludge show that the flat-bottom tank requires from four to eight times more water than a conical-bottom tank, depending on the efficiency of the sludge system and the amount of sludge deposited.

Tests were carried out to determine the amount of water required to remove the sludge from tanks. In the case of a flat-bottom tank 22 ft. in diameter, after 12 hr. operation, during which time 120,000 gal. of water had been treated, the sludge amounted to approximately 520 lb. About 5000 gal. of water was used to remove it, and even after that the tank was not clean by any means. When the tank was drained it was found that sludge had accumulated to a depth of 3 ft. all around the edge of the tank and there was a great deal of sludge between the sludge lines.

A similar test was made with a conical-bottom treating tank 28 ft. in diameter. After 60 hr. operation, during which time 1,000,000 gal. of water had been treated and the sludge deposit amounted to over 4000 lb., it was found that 2300 gal. of water was sufficient to remove the sludge completely. Other advantages of the conical-bottom tank, such as rate of upflow, are discussed in the original article. (*Railway Engineering and Maintenance*, vol. 19, no. 7, July 1923, pp. 273–276, 5 figs., *d*)

REFRIGERATION

SPECIFIC VOLUME OF SATURATED AMMONIA VAPOR, C. S. Cragoe, E. C. McKelvy, and G. F. O'Connor. The specific volume of saturated ammonia vapor was measured in the temperature interval −50 to +50 deg. cent. by two methods, one involving a direct determination of the mass of the vapor contained in a known volume, and the other an optical method, involving measurements of the index of refraction of the vapor.

Three pienometers of different total volumes were used in the measurements by the direct method. The effect of adsorption was studied and found to be of a magnitude comparable with the limit of accuracy of that method.

Two methods of measurement were used, and the possible sources of error in the two methods are discussed. The final results are represented closely by the empirical equation:

$$\log_{10} u' = 300\left[\frac{6.46344}{\theta} - 0.106887 + 0.0356803 \log_{10}\theta\right] + 0.0862366\sqrt{406.1 - \theta} + 0.002667\ (406.1 - \theta)$$

in which u' is expressed in cubic centimeters per gram and θ in degrees absolute (deg. abs. = deg. cent. + 273.1). (*Scientific Paper of the Bureau of Standards*, no. 467, Mar. 17, 1923, pp. 707–735, 4 figs., *e*)

VARIA

American Continent Hydroelectric Power Scheme

Data concerning a novel power scheme to cover the entire continent of North America, that is, not only the United States proper, but also Alaska and Canada.

The new scheme is based on what is called the diversity factor of the main river systems of the North American continent, together with the oscillating power demand over the entire continent due to differences in time. If one looks at North America as one vast hydraulic engine, it may be conceived as throbbing with power throughout the year. It is not only the regular water levels that oscillate. The flood crests too are spaced out over the year, and form headwaters to sea level. As the floods move down the rivers past successive power plants they lengthen the period of maximum power in their water sheds. The lakes, including the Great Lakes, are likewise variable in volume and level in a cycle running almost seven years from low to high and the excess water of the peak years can be impounded and used as a booster for a continental power system.

In addition to the storage of water from the lake system, storage works may be built to realize the utmost constant power from streams with high head of water. On the bulk of the low-head streams, however, power-plant construction will take the form of "over development," that is, the construction of power plants in series from headwaters to mouth to develop the flood power of the stream as it comes down.

It is claimed that a smaller total of storage will be required to produce the same amount of constant power from a continental system than would be needed for plants developed apart. The extent to which the Great Lakes alone could be used as reservoirs of power to boost a continental system through a seasonal or cyclical low-water period seems almost without limit. Storage of one extra foot of water in the Michigan-Huron system would make available power in enormous quantitise.

The problem of the transmission of power in a manner that would make the continental system possible is not considered by the authors of the article as excessively difficult of solution. Two hundred and twenty thousand volt power lines are already in commercial operation. To make the water power of the Sierras available to the prairie states lines up to 350,000 volts may be required and the Tribune's investigations point to the necessity of using still higher voltages, figures of 1,000,000 and 2,000,000 volts being mentioned as within the bounds of possibility within comparatively short time.

It is claimed that a continental system will develop far more primary power than America will need for generations, but there are forces now in evidence in agriculture, transportation and industry which will make it increasingly possible to coördinate industrial effort to periods when the greatest volume of power is available. It seems highly probable to the Tribune investigators that in the streams of Canada and Alaska may lie the solution of the whole low-water problem. These rivers head in snow and ice and come to full flood as the southern streams are receding. From their connection with lake systems it seems probable that the application of storage methods will make it possible to impound the flood from melting snow and ice for regulated discharge over the period in which the streams of the south reach their low level.

The minimum potential water power of the United States based on the average periods of lowest flow in each year is estimated to be about twenty-eight million horsepower. This does not include the smaller streams and leaves out Canada. The horsepower capable of development under a continental system is estimated to amount to two hundred and eighty million horsepower. This is approximately more than twice the power of all kinds now installed in the United States and most of this installed power is employed for only brief periods of time. (*Chicago Sunday Tribune*, Aug. 5, 1923, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Stationary Steam-Generating Units

Preliminary Draft of Another Code in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

IN 1918 the Committee on Power Test Codes was reorganized by the Council of The American Society of Mechanical Engineers to revise and enlarge the Power Test Codes of the Society published in 1915. The committee consists of a main committee of twenty-five members under the chairmanship of Fred R. Low, and nineteen individual committees of specialists who are drafting test codes for the various prime movers and the other apparatus which comprise power-plant equipment.

The individual committee which developed the Test Code for Stationary Steam-Generating Units is headed by Edwards R. Fish as Chairman, the other members being Arthur D. Pratt, Alex. D. Bailey, Albert A. Cary, and Edwin B. Ricketts. William N. Best, now deceased, was also a member of this committee.

The committee and the Society will welcome suggestions for corrections or additions to this draft of its code from those who are specially interested in the manufacture and use of stationary steam generating units. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 The Test Code for Stationary Steam-Generating Units applies to the boiler, fuel-burning apparatus of whatsoever nature, superheaters, and economizers, but not to apparatus required for their operation such as engines or motors for driving stokers, feed pumps, etc. Economizers are considered as part of the generating units, and the form of test report provides for their inclusion in an overall test. They may be divided into two general classes, (*a*) separate economizers, being those with their own housing and connected to the boilers with flues, and (*b*) integral economizers, which are contained within the boiler setting and through which a part of the boiler circulating water may or may not pass.

Observations when testing steam-generating units equipped with the first-named class may readily be separated so as to either include or exclude the economizer in the results. In the case of the second class, however, it is practically impossible to segregate the economizer from the boiler, and tests of units so equipped should be conducted and reported as if the economizer was a part of the boiler proper, full notes being made to that effect.

2 Boiler testing should not be lightly undertaken by any one who has not had some training under an experienced testing engineer if reliable results are to be expected. The whole matter should be thoroughly understood, both theoretically and practically. Accurate tests depend very largely upon the care and faithfulness of the observers. It is much easier to make mistakes than is realized by those who are not familiar with practical testing.

The absolute accuracy of the results of a boiler test, even when conducted with the greatest care, is doubtful, but there is as yet no possible basis upon which to determine what the probable limits of error might be. It is generally conceded, however, that there are several sources of indeterminate error, the more important of which are discussed below. The limits of accuracy of a test may very reasonably be taken to be within plus or minus 3 per cent.

One of the sources of probable error is the sampling of coal. Even when the greatest care is taken to obtain a representative sample, there may be an indeterminate error in ascertaining the heating value of the coal, even though the laboratory analysis is most reliable. With modern apparatus these laboratory determinations should be substantially correct as regards the sample tested; but the question as to how truly the same represents the whole is always present and cannot be answered indubitably.

Another source of error is the moisture contained in the coal. As explained in the preceding paragraph, the sampling is more or less uncertain. It is contended by some that if the attempt is made to determine the moisture during the test, the methods of drying and weighing are unreliable; while others contend that though the moisture as determined in the laboratory is accurate so far as the sample delivered to the laboratory is concerned, this sample probably does not represent the bulk of the coal actually burned, since there must inevitably have been more or less loss of moisture during the collection, preparation, and handling of the sample.

Similarly, it is problematical whether the samples collected for the determination of the moisture in steam and for gas analysis are representative of the bulk, although the testing of the samples obtained may be quite accurate.

It is not unusual for heat balances to be reported to the nearest B.t.u. and to the nearest one-tenth of 1 per cent. But the present state of the art of boiler testing does not provide means for attaining anything like this accuracy. In general, results should be reported only to the nearest significant figure. Reporting results of any kind in small units is likely to convey an erroneous idea as to the real accuracy of the figures.

It is therefore quite logical in the case of guarantee tests that a substantial compliance with the guarantee be accepted as full compliance therewith. A limit of tolerance should be agreed upon beforehand by the parties to the test. The amount of this tolerance might well bear some relation to the care exercised in arranging the details and in the conducting of the test.

Object and Preparations

3 Definitely determine the object of the test and keep it continuously in mind. Take the dimensions, note the physical conditions, examine for leakage, install the testing appliances, etc., as pointed out in the "General Instructions," Pars. 1 to 4, and make preparations for the test accordingly.

4 Determine the character of the fuel to be used.

5 In guarantee tests with fuel of a specified heating value or other characteristics, there should be a clear understanding as to the permissible variation from the specified characteristics.

In guarantee tests of a waste-heat boiler, the performance of which is dependent upon gas weight and entering gas temperature, there should be a clear understanding as to the method to be used in the determination of the gas weight and the measurement of the gas temperature.

6 If the size of coal is to be reported, it should be determined in accordance with Pars. — to — of the Test Code on Fuels.

Instruments and Apparatus

7 The instruments and apparatus required for boiler tests are:

(*a*) Scales for weighing coal, oil, or other fuel, ashes, furnace refuse, etc.
(*b*) Graduated scales attached to the water glasses
(*c*) Tanks or tanks and scales for volumetric or weight measurement of water
(*d*) Meters or other apparatus for measuring gaseous fuels
(*e*) Pressure gages, thermometers, pyrometers and draft gages
(*f*) Calorimeter for determining the quality of the steam
(*g*) Gas-sampling and analyzing apparatus.

8 Full directions regarding the design, use, and calibration of the above-mentioned appliances are given in the Code on Instruments and Apparatus, Pars.—to—.

9 As no two plants are alike, it is quite impracticable to do more than suggest how and where the various instruments should be located.

9a Fuel-weighing apparatus should be near the point where the fuel is to be used, under direct observation of and convenient to the one in charge of the test. The weighing of refuse may be done at any convenient point.

9b The water-glass scale should be so attached that the breaking of the glass will not disturb the scale.

9c The water-weighing or measuring apparatus if other than a meter should be arranged in an easily accessible place and made as convenient as practicable. It should also be under the direct observation of the one in charge of the test.

9d Meters or other apparatus for measuring gaseous fuel may be placed in such locations as conditions dictate.

9e Pressure gages should be away from any disturbing influences, such as extreme heat, and in a position to be easily read. Thermometers for determining atmospheric temperatures should be placed so as to give an average indication away from cold or hot drafts, etc.

A thermometer well for measuring feedwater temperatures should be as close to the boiler inlet as possible and the pipe between boiler and thermometer should be well protected with heat-insulating covering.

Saturated-steam temperatures may be measured at any point in the steam pipe where the pressure is the same as that where the temperature is desired, care being taken that the well is not cooled by the condensate. The temperature and pressure of superheated steam should be measured as close to the outlet of the superheater as possible, eliminating all losses by pressure drop and radiation between the superheater and thermometer.

Pyrometers of any type must have the part on which the heat impinges so located that the temperature which it is desired to measure is actually obtained. Much experience and good judgment are essential in order to obtain even approximately reliable readings.

Draft at the gas outlet is usually measured if nowhere else. It is often desirable to know the draft at other points of the setting, in which cases the several locations should be chosen to suit the information wanted. Care should be exercised to see that the ends of the connecting pipes are not obstructed and that the open ends are not subject to other than static pressures. All joints of draft-gage connections must be tight.

9f The sampling tube of the calorimeter should be as close to the point at which the quality of steam is desired as possible. All exposed piping in which condensation might influence the result must be well lagged. Ordinarily the quality of the steam leaving the boiler, or that entering the superheater, is desired.

9g Analysis of the exit gases is usually what is taken, but very frequently analyses are wanted from other points. Sample tubes must be so located that only the gas to be analyzed enters the tube and precautions taken against the possibility of inleakage of air anywhere in the line. The gas-analyzing apparatus should be in a readily accessible and protected place with good light and convenient facilities. See Code on Instruments and Apparatus, Pars.—to—.

Operating Conditions

10 Determine what the operating conditions and method of firing should be to conform with the object in view, and see that they prevail as nearly as possible throughout the trial.

11 The duration of tests to determine the efficiency of a steam-generating unit burning coal either hand or stoker fired should preferably be 24 hours, but where operating conditions do not permit or other considerations make it advisable or necessary the length of test may be reduced to not less than 10 hours. When the rate of combustion is less than 25 lb. of coal per sq. ft. of grate surface per hour the test should be continued until a total of 250 lb. per sq. ft. of grate area has been burned, except that in cases where a type of stoker is used that does not permit the quantity of fuel and (or) the condition of the fuel bed to be accurately estimated the duration of test should not be reduced below that required to minimize the error.

12 In the case of a unit using pulverized fuel the duration of test should be not less than 6 hours, and for liquid or gaseous fuel not less than 4 hours.

13 In the case of a waste-heat unit, where the operation of the industrial furnace is continous and furnace conditions are constant, the duration of the test should be not less than 6 hours. Where the industrial-furnace operation is in cycles, the test should be of such duration as to cover at least one cycle of furnace operation.

14 In tests conducted under plant-operation conditions where the service requires continuous operation night and day, with frequent shifts of firemen, the duration of test should be at least 24 hours. Likewise in such tests, either of a single boiler or of a plant of several boilers which operate regularly a certain number of hours and during the remainder of the day are banked, the duration should be not less than 24 hours.

15 The duration of tests to determine the maximum evaporative capacity of a steam-generating installation, when the efficiency is not determined, should be not less than 2 hours, unless otherwise agreed upon.

Starting and Stopping

16 Combustion, fuel, draft, and temperature conditions, the water level, rate of feeding water, rate of steaming, and the steam pressure should be as nearly as possible the same at the end as at the beginning of the test. If an economizer is included in the unit tested the average temperature of the water within it should be the same at the start and end of test.

17 To secure the desired equality of conditions with hand-fired boilers, the following method should be employed:

The furnace being well heated by a preliminary run at the same combustion rate that will prevail during the test and sufficiently long to thoroughly heat the setting, burn the fire low and thoroughly clean it, leaving enough live coal spread evenly over the grate (say, from 2 to 4 in.) to serve as a foundation for the new fire. Note quickly the thickness of the coal bed as nearly as it can be estimated or measured, also the water level, the steam pressure, and the time, and record the latter as the starting time. Fresh coal should then be fired from that weighed for the test, the ashpit thoroughly cleaned, and the regular work of the test proceeded with.

Before the end of the test the fire should again be burned low and cleaned in such a manner as to leave the same amount of live coal on the grate as at the start. When this condition is reached, observe quickly the water level, the steam pressure, and the time, and record the latter as the stopping time. If the water level is lower or higher than at the beginning, a correction should be made by computation, not by feeding additional water. Finally remove the ashes and refuse from the ashpit.

In a plant containing several boilers, where it is not practicable to clean them simultaneously, the fires should be cleaned one after the other as rapidly as may be, and each one after cleaning charged with enough coal to maintain a thin fire in good working condition.

After the last fire is cleaned and in working condition, burn all the fires low (say, 4 to 6 in.), note quickly the thickness of each, also the water levels, steam pressure, and time, which last is taken as the starting time. Likewise, when the time arrives for closing the test the fires should be quickly cleaned one by one, and when this work is completed they should all be burned low the same as at the start, and the various final observations made as before stated.

In the case of a large boiler having several furnace doors requiring the fire to be cleaned in sections one after the other, the above directions pertaining to starting and stopping in a plant of several boilers may be followed.

18 To obtain the desired equality of conditions when a mechanical stoker is used, the above procedure should be modified as follows:

Stokers should be in operation at approximately the same rate that will prevail during the test for at least 12 hours before starting test. At the start and finish of the test, level the coal in stoker hopper. Make starting and stopping observations as in hand fired tests.

18a *Stokers of the Continuous-Dumping Type.* The desired operating conditions, i.e. speed and stroke of coal-feeding mechanism, speed of grate, intensity of draft or blast, and rate of water feed should be maintained as nearly constant as possible for at least one hour, and preferably for two hours, before starting and stopping the test.

18b *Stokers of the Intermittent-Dumping Type.* Proceed as above, except that stokers should be cleaned about one hour before starting and before stopping the test.

19 To obtain the desired equality of conditions when pulverized, liquid, or gaseous fuel is used, the following method should be employed:

The boiler or boilers to be tested should be operated before the start of the test under the fuel, furnace, and combustion conditions which are to be maintained throughout the test for a period of not less than three hours. Fuel temperature, fuel pressure and draft conditions should be kept as nearly constant as possible during this period and throughout the test. The references above for hand-fired tests as to starting and stopping observations hold also for pulverized-, liquid-, and gaseous-fuel tests.

20 In the case of a waste-heat boiler set in connection with an industrial furnace the operation of which is continuous, the rules governing the starting and stopping of tests with pulverized, liquid, or gaseous fuels will apply. Where the industrial furnace operates in cycles, the start and end of the test should be at the same point of two or more successive cycles. Starting and stopping observations should be in accordance with the previous rules.

Records

21 The records of data should be obtained as pointed out in Tables 1*a* to 12*b*. Readings of the instruments at 15-minute intervals are usually sufficient. If there are sudden and wide fluctuations, the readings should be taken at 10-minute intervals, or at such frequency as may be necessary to determine the true nature of the variation.

22 The approximate quantity of fuel needed each hour should be determined, and if the quantity required and inconvenience due to lack of room is not too great, the whole amount should be delivered on the firing floor at the beginning of each hour. If any is left at the end of the hour the quantity should be estimated. In this way the amount of fuel used per hour can be determined and the approximate results be followed from hour to hour.

If the whole amount cannot be delivered at the beginning of the hour, convenient quantities may be weighed out at appropriate intervals so as to come out about even at the end of the hour. When hopper scales are used, receiving coal from bunkers and discharging directly into furnace hoppers, hourly quantities may be roughly determined by estimating furnace conditions. These

hourly quantities should be properly noted on the log sheet. They are taken as a matter of convenience and guide, but only the totals are to be used in the final calculation.

23 The records should be such as to ascertain also the approximate consumption of feedwater each hour, and thereby determine the degree of uniformity of evaporation. The maintenance of a uniformity of evaporation is greatly facilitated by the use of some form of graphic recording steam meter, which should be so placed as to keep continuously before the operator the rate of evaporation. Since the indications of this meter are not used in any of the test calculations, extreme accuracy is not essential.

24 *Quality of Steam.* If the boiler does not produce superheated steam, the quality of the steam should be determined by the use of a throttling or separating calorimeter in the manner pointed out in the Code on Instruments and Apparatus, Pars. — to —. If the boiler has superheating surface, the temperature of the steam should be determined by the use of a thermometer inserted in a thermometer well, as pointed out in Par. — of the above-mentioned code.

25 *Sampling Fuel.* During the progress of the test fuel should be regularly sampled for purposes of analysis, as pointed out in the Test Code on Fuels, Pars. — to —.

26 *Ashes and Refuse.* The ashes and refuse withdrawn from the furnace and ashpit during the progress of and at the end of the test should be weighed, as far as possible, in a dry state. If wet, the amount of moisture should be ascertained and allowed for, a sample being taken and dried for this purpose. This sample may also serve for analysis.

Ash sampling is at best subject to large errors, and every precaution should be taken to insure as representative a sample as possible. If sufficiently hot to allow combustion to proceed, ash should be thoroughly quenched with water immediately after dumping into the ashpit. Enough time should elapse before weighing to permit the heat of the refuse to drive out most of this moisture. If possible, all the ash should then be passed through a crusher, thoroughly mixed, and reduced to a laboratory-size sample by successive quartering. If it is impracticable to crush all the ash, the clinkers and fines should be placed in separate piles, and each pile weighed and sampled separately, the two samples being combined in proportion to the relative weights of their respective piles.

27 *Calorific Tests and Analyses of Fuels.* The quality of the fuel and of the furnace ash and refuse should be determined by calorific tests and analyses of the fuel sample above referred to. Directions for obtaining samples and making these tests and analyses will be found in the Test Code on Fuels under the headings "Fuel Calorimeters" and "Fuel-Analysis Apparatus," Pars. — to —.

28 *Analyses of Flue Gases.* For approximate determinations of the composition of the flue gases, the Orsat apparatus or some modification thereof should be employed. Gas samples should preferably be taken continuously, but if momentary samples are obtained the analyses should be made as frequently as possible, noting the furnace and firing conditions at the times the sample are drawn. Where the firing is intermittent, gas samples should be taken at such intervals that the complete firing cycle will be covered by the average of individual readings. If the sample drawn is a continuous one the intervals may be made longer. Where the unit includes an economizer, gas analyses should be made at both boiler and economizer outlet.

Fuller directions will be found in the Code on Instruments and Apparatus, under the heading "Gas-Analysis Apparatus," Pars. — to —.

29 *Smoke Observations.* In tests requiring a determination of the amount of smoke produced, observations should be made regularly throughout the trial at intervals of five minutes, or if necessary, of one minute. For observations covering a period of one or more single firings with solid fuel, the intervals should be one-quarter minute or less.

30 *Appliances and Methods Pertaining to Smoke Determination.* No wholly satisfactory methods for either quantitative or qualitative smoke determinations have yet come into use, nor have any reliable methods been established for definitely fixing even the relative density of the smoke issuing from chimneys at different times. One method commonly employed, which answers the purpose fairly well, is that of making frequent visual observations of the chimney at intervals of one minute or less for a period of one hour and recording the observed characteristics according to the degree of blackness and density, and giving to the various degrees of smoke an arbitrary percentage value rated in some such manner as the following:

SMOKE PERCENTAGES

Dense black	100	Light gray	20
Medium black	80	Very light	5
Dense gray	60	Trace	1
Medium gray	40	Clear chimney	0

The color and density of smoke depend somewhat on the character of the sky or other background, and on the air and weather conditions obtaining when the observation is made, and these should be given due consideration in making comparisons. Observations of this kind are also subject to personal errors and errors of judgment. Nevertheless these methods are useful especially when the results are plotted, according to the percentage scale determined on, so that a graphic representation of the changes can be shown. The observations should be considered as only roughly indicating the smoke conditions and are comparable only when made by the same observer.

Various forms of charts and clouded-glass arrangements for comparing and fixing smoke densities have been proposed, and to some extent used, but these have proved more or less unsatisfactory and they are subject to personal errors, and to sky, wind, and weather conditions, the same as the simpler method above described.

Among the chart methods referred to, the use of the Ringelmann smoke chart is perhaps the most familiar.

Another method of smoke determination consists in the use of a narrow, flat metal plate suspended in the flue, the character of the smoke being indicated by the amount and quality of the soot and dust deposited upon the plate in a given time. This method, like others, is useful in furnishing a means of comparison in different cases rather than a means of exact determination.

Among the latest methods brought out for indicating and recording the density of smoke is one depending on the variations in the electrical conductivity of the metal selenium due to variations in the intensity of light shining upon it. Openings are provided on either side of the flue directly opposite each other. The selenium is located at one opening and a strong light at the other. The intensity of the light rays falling on the selenium varies with the density of the smoke. A milliampere meter in circuit with the selenium cell registers the variations.

Ringlemann Smoke Chart. A Ringlemann smoke chart is shown with full-size spacing in Fig. 1. To use this chart, four cards are ruled like those shown, though covering a much larger area, and placed in a horizontal row about 50 ft. from the observer, and in line between him and the chimney, together with two other cards, one of which is white and the other solid black. The observer glances rapidly from the chimney to the cards and judges which one corresponds with the color and density of the smoke. He makes these observations every minute, or oftener if desired, recording the number of the card representing the character of the smoke at the instant of observation. The results are then plotted on a chart, and the variations shown graphically.

The lines in cards 1 to 4 are respectively 1, 2.3, 3.7, and 5.5 mm. thick, and the spaces 9, 7.7, 6.3, and 4.5 mm. The lines should be made with black india ink.

FIG. 1 RINGLEMANN SAMPLE CHART

31 *Chart.* In trials having for an object the determination and exposition of the complete boiler performance, the entire log of readings and data should be represented graphically. See Appendix A.

CALCULATION OF RESULTS

32 The test report should state the source of numerical constants or other values used in the computations.

33 It is recommended that a record be kept of the energy used by auxiliaries immediately connected with the steam generating unit being tested and a specific note made thereof; no deductions, however, shall be made on the report forms or in computing results unless the object of the test so requires, in which case the report should specifically so state. This applies to steam or power used in driving stokers or other fuel-feeding apparatus, oil burners, fans, feed pumps, soot blowers, etc.

DATA AND RESULTS

34 The data and results should be reported in accordance with the tables given herewith, using the proper table for the class of fuel burned. If necessary, items of data not provided for may be added, or if certain items are not required such may be omitted, as may conform to the object of the test. Unless otherwise indicated, the quantities should be the average of the observations.

APPENDIX A

CHART OF OBSERVED DATA

APPENDIX B

ISOCALORIFIC AND ISOVOLATILE CURVES

TABLE 1a DATA AND RESULTS, TEST OF STATIONARY STEAM-GENERATING UNIT. SOLID FUELS—AS FIRED—DRY

GENERAL INFORMATION

(1) Date of test
(2) Location of plant
(3) Owner of plant
(4) Maker and type of boiler
(5) Maker and type of superheater
(6) Maker and type of economizer
(7) Maker and type of air heater
(8) Maker and type of fuel-burning equipment
(9) Test conducted by
(10) Object of test

DESCRIPTION, DIMENSIONS, ETC.

(11) Boiler heating surface ..... sq. ft.
(12) Superheater surface ..... sq. ft.
(13) Economizer surface ..... sq. ft.
(14) Air heater surface ..... sq. ft.
(15) Grate surface ..... sq. ft.
(16) Fuel burning equipment
(17) Draft
(18) Fuel
(19) Volume of combustion space ..... cu. ft.
(20) Furnace, center of grate to nearest heating surface ..... ft.
(21) Furnace volume per sq. ft. boiler heating surface ..... cu. ft.

FUEL AND GAS ANALYSES AND DATA

Fuel Proximate Analysis—Dry—As Fired

(22) Volatile matter ..... per cent
(23) Fixed carbon ..... per cent
(24) Ash ..... per cent
(25) Moisture (as fired) ..... per cent
(26) B.t.u. per lb. (as fired)
(27) B.t.u. per lb. (dry)
(28) Fusion temperature of ash ..... deg. fahr.
(29) Size of coal as fired

Fuel Ultimate Analysis

(30) Carbon ..... per cent
(31) Hydrogen ..... per cent
(32) Oxygen ..... per cent
(33) Nitrogen ..... per cent
(34) Sulphur ..... per cent
(35) Ash ..... per cent

Gas

(36) Gas analysis, furnace:
Per cent CO_2..... O_2..... CO..... N_2..... SO_2.....
(37) Gas analysis, boiler outlet:
Per cent CO_2..... O_2..... CO..... N_2..... SO_2.....
(38) Gas analysis, economizer:
Per cent CO_2..... O_2..... CO..... N_2..... SO_2.....
(39) Gas analysis, air heater:
Per cent CO_2..... O_2..... CO..... N_2..... SO_2.....
(40) Dry gas per lb. fuel, furnace (as fired, dry) ..... lb.
(41) Dry gas per lb. fuel, boiler outlet (as fired, dry) ..... lb.
(42) Dry gas per lb. fuel, economizer (as fired, dry) ..... lb.
(43) Dry gas per lb. fuel, air heater (as fired, dry) ..... lb.
(44) Dry gas per lb. fuel, theoretical (as fired, dry) ..... lb.
(45) Air supplied per lb. fuel, furnace (as fired, dry) ..... lb.

Pressures and Drafts

(46) Moisture in air ..... lb. per lb. air
(47) Steam pressure by gage, boiler ..... lb. per sq. in.
(48) Steam pressure by gage, superheater outlet ..... lb. per sq. in.
(49) Air pressure in ashpit zone, at burners ..... in. of water
(50) Draft in furnace ..... in. of water
(51) Draft at boiler outlet ..... in. of water
(52) Draft at economizer outlet ..... in. of water
(53) Draft at air-heater outlet ..... in. of water

Temperatures

(54) Steam temperature ..... deg. fahr.
(55) Moisture in steam ..... per cent
(56) Superheat ..... deg. fahr.
(57) Temperature of air surrounding boiler, T_1 ..... deg. fahr.
(58) Temperature of air entering air heater, T_2 ..... deg. fahr.
(59) Temperature of air leaving air heater, T_3 ..... deg. fahr.
(60) Temperature of air for combustion, T_4 ..... deg. fahr.
(61) Temperature of air furnace, T_5 ..... deg. fahr.
(62) Temperature of gases leaving boiler, T_6 ..... deg. fahr.
(63) Temperature of gases leaving economizer, T_7 ..... deg. fahr.
(64) Temperature of gases leaving air heater, T_8 ..... deg. fahr.
(65) Temperature of feedwater entering boiler, T_9 ..... deg. fahr.
(66) Temperature of feedwater entering economizer, T_{10} ..... deg. fahr.
(67) Temperature of water in boiler at point where gases leave boiler, T_{11} ..... deg. fahr.
(68) Temperature of fuel, T_{12} ..... deg. fahr.

Hourly Quantities

(69) Duration of test ..... hr.
(70) Fuel as fired per hour ..... lb.
(71) Dry fuel per hour ..... lb.
(72) Fuel as fired per sq. ft. of grate per hour ..... lb.
(73) Fuel as fired per sq. ft. of retort or per burner per hour ..... lb.
(74) Dry fuel per sq. ft. of grate per hour ..... lb.
(75) Dry fuel per retort or per burner per hour ..... lb.
(76) Combustion space per lb. coal per hour (as fired, dry) ..... cu. ft.
(77) Refuse per hour ..... lb.
(78) Actual water per hour ..... lb.
(79) Factor of evaporation ..... lb.
(80) Equivalent evaporation per hour ..... lb.
(80a) Boiler horsepower, average ..... hp.

Refuse

(81) Refuse, per cent of fuel (as fired, dry) ..... per cent
(82) Percentage of combustible in refuse ..... per cent
(83) Carbon burned per lb. fuel (as fired, dry) ..... lb.

Evaporation

(84) Actual evaporation per lb. fuel (as fired, dry) ..... lb.
(85) Equivalent evaporation per lb. fuel (as fired, dry) ..... lb.
(86) Equivalent evaporation per lb. dry fuel ..... lb.
(87) Equivalent evaporation per sq. ft. heating surface per hr ..... lb.
(88) Number of 1000 B.t.u. absorbed per sq. ft. of boiler heating surface per hour ..... B.t.u.
(89) Percentage rating ..... per cent

Efficiency

(90) Efficiency of boiler, superheater, furnace, grate, and air heater ..... per cent
(91) Efficiency including economizer ..... per cent

TABLE 1b HEAT BALANCE OF STEAM-GENERATING UNIT, SHORT FORM. SOLID FUELS

Item	B.t.u.	Per cent
(92) = Heat absorbed by water and steam in boiler and superheater	....	....
(93) = Heat absorbed by water in economizer	....	....
(94) = Heat loss due to moisture in coal	....	....
(95) = Heat loss due to water from combustion of hydrogen	....	....
(96) = Heat loss due to moisture in air	....	....
(97) = Heat loss due to dry chimney gases	....	....
(98) = Heat loss due to incomplete combustion of carbon	....	....
(99) = Heat loss due to unconsumed combustible in refuse	....	....
(100) = Heat loss due to unconsumed hydrogen and hydrocarbons	....	....
(101) = Heat loss due to radiation and unaccounted for	....	....

TABLE 1c COMPUTATIONS FOR TEST OF STATIONARY STEAM-GENERATING UNIT. SOLID FUEL

EXPLANATION OF SYMBOLS

Wherever CO_2, O_2, CO and N_2 are used they are the percentages by volume of these constituents in the gases of combustion.

H = total heat (in B.t.u. per lb.) of saturated steam at the boiler outlet pressure.
H_1 = total heat (in B.t.u. per lb.) of superheated steam at the superheater outlet pressure.
h = total heat (in B.t.u. per lb.) in feedwater at boiler inlet.
h_1 = total heat (in B.t.u. per lb.) in feedwater at economizer inlet.
L = latent heat (in B.t.u. per lb.) in steam at pressure in steam main.
t_2 = temperature of steam after expansion in calorimeter.
T_{13} = initial temperature of water for quenching ashes.
T_{14} = final temperature of water for quenching ashes.
W = weight of water used per hour for quenching ashes.

GENERAL

If test is on a dry basis, draw a line through "as fired" wherever the words "as fired, dry" appear together, and vice versa. Whichever basis is chosen must be followed throughout. Percentage results in heat balance will be the same in either case.

Item 11 to 14—Heating surface shall consist of that portion of the surface of the heat-transfer apparatus exposed to both the gases being cooled and the fluid being heated at the same time computed on the gas side.

Item 15—The projected area within the four walls surrounding the grate.

Item 17—State whether natural, forced, induced or a combination of one or more kinds of draft were employed.

Item 18—State general class of fuel, as anthracite, bituminous, wood refuse, etc. Also give district where produced.

Item 19 = The cubic space provided for the combustion of fuel before the products of combustion pass through any heating surface.

Items 22 to 35 = As fired analysis items = dry analysis items $\times \left(1 - \frac{\text{Item } 25}{100}\right)$

$$Items\ 40\ to\ 43 = \frac{11\,CO_2 + 8\,O_2 + 7(CO + N_2)}{3(CO_2 + CO)} \times Item\ 83.$$

Use data from *Items* 36 to 39.

$$Item\ 44 = 12.52 \times Item\ 83 + \frac{26.56 \times Item\ 31 + 3.325 \times Item\ 34 + Item\ 33}{100}$$

$$Item\ 45 = Item\ 40 + \frac{9 \times Item\ 31}{100} - \frac{100 - Item\ 81}{100}$$

Item 46—For methods of determination see code on Instruments and Apparatus Par.—.

Item 55—Determine either from charts or the following formula:

$$100 \times \frac{H - 1150.4 - 0.47 \times (t_2 - 212)}{L}$$

Item 77 = combined weight of ashes and cinders produced during test divided by Item 69. In tests of large boilers where it is impracticable to determine the amount of refuse by weighing, Item 77 may be calculated as follows:

$$Item\ 77 = \frac{Item\ 24}{100 - Item\ 82} \times Item\ 70\ (\text{or } 71)$$

$$Item\ 79\ (\text{For saturated or wet steam}) = \frac{H - \frac{L \times Item\ 55}{100} - h}{970.4}$$

$$(\text{For superheated steam}) = \frac{H_1 - h}{970.4}$$

$$Item\ 80 = Item\ 78 \times Item\ 79.$$

$$Item\ 80a = \frac{Item\ 80}{34.5}$$

$$Item\ 81 = \frac{Item\ 77}{Item\ 70\ (\text{or } 71)}$$

$$Item\ 83 = \frac{Item\ 30}{100} - \frac{Item\ 81 \times Item\ 82}{10{,}000}$$

$$Item\ 84 = \frac{Item\ 78}{Item\ 70\ (\text{or } 71)}$$

$$Item\ 85 = \frac{Item\ 80}{Item\ 70}$$

$$Item\ 86 = \frac{Item\ 80}{Item\ 71}$$

$$Item\ 87 = \frac{Item\ 80}{Item\ 11}$$

$$Item\ 88 = \frac{Item\ 80 \times 970.4}{Item\ 11}$$

$$Item\ 89 = \frac{Item\ 88a \times 10}{Item\ 11}$$

$$Item\ 90 = \frac{Item\ 85\ (\text{or } 86) \times 970.4}{Item\ 26\ (\text{or } 27)}$$

$$Item\ 91 = \frac{Item\ 85\ (\text{or } 86) \times 970.4 + (h - h_1) \times Item\ 84}{Item\ 26\ (\text{or } 27)}$$

TABLE 1*d* HEAT-BALANCE COMPUTATIONS, SHORT FORM, SOLID FUELS

Item

(92) = *Item* 85 (or 86) × 970.4

(93) = *Item* 84 × ($h - h_1$)

(94) = $\frac{Item\ 25}{100} \times (1090.7 + 0.455\ T_6 - T_{12})$

(95) = $\frac{Item\ 31}{100} \times 9 \times (1090.7 + 0.455\ T_6 - T_{12})$

If economizer is installed without air heater, substitute T_7 for T_6; if air heater is installed substitute T_5 for T_6 in Items 94, 95, 96 and 97.

(96) = *Item* 45 × *Item* 46 × 0.455 ($T_6 - T_4$).

This loss is small and is frequently included in Item 100.

(97) = *Item* 41 (42 or 43) × 0.24 ($T_6 - T_1$).

If boiler and superheater use Item 41, if economizer use Item 42, if air heater use Item 43.

(98) = $\frac{CO}{CO_2 + CO} \times Item\ 83 \times 10160$

If boiler alone use analysis from Item 37, if economizer use Item 38, if air heater use Item 39.

(99) = $\frac{Item\ 81 - Item\ 24}{100} \times 14600$

(100) = *Item* 26 (or 27) − (Sum of *Items* 92 to 99, inclusive).

TABLE 2*b* HEAT BALANCE OF STEAM-GENERATING UNIT COMPRISING BOILER AND SUPERHEATER, WITH OR WITHOUT INTEGRAL ECONOMIZER. SOLID FUELS

Item	HEAT VALUES	B.t.u.	Per cent
(92)	= Heat per pound coal as fired (high heating value)	....	....
(93)	= Heat absorbed by water and steam in boiler and superheater	....	....
(94)	= Heat absorbed by steam in superheater	....	....
	UNAVOIDABLE LOSSES		
(95)	= Heat loss due to moisture in coal, moisture accompanying theoretical air and water from combustion of hydrogen, up to T_{11}	....	....
(96)	= Heat loss due to theoretical dry gases, T_4 to T_{11}	....	....
(97)	= Total unavoidable losses	....	....
	OTHER LOSSES		
(98)	= Heat loss due to combustible in refuse	....	....
(99)	= Heat loss due to sensible heat in refuse, cinders, and soot	....	....
(100)	= Heat loss due to unburned gaseous combustibles	....	....
(101)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{11}	....	....
(102)	= Heat loss due to theoretical dry gases, moisture in coal, moisture accompanying theoretical air, and moisture from combustion of hydrogen, T_{11} to T_6	....	....
(103)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_{11} to T_6	....	....
(104)	= Heat loss due to air and moisture leaking through boiler setting, T_1 to T_6	....	....
(105)	= Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....

TABLE 2*d* HEAT-BALANCE COMPUTATIONS FOR A STEAM-GENERATING UNIT COMPRISING BOILER AND SUPERHEATER WITH OR WITHOUT INTEGRAL ECOMOMIZER. SOLID FUELS

Item

(92) = *Item* 26 (or 27)

(93) = *Item* 85 (or 86) × 970.4

(94) = ($H_1 - H$) × *Item* 84

(95) = $(1090.7 + 0.455\ T_{11} - T_{12}) \times \frac{(Item\ 25 + 9 \times Item\ 31)}{100}$
$+ (Item\ 44 - Item\ 83) \times Item\ 46 \times 0.455 \times (T_{11} - T_4)$

(96) = *Item* 44 × ($T_{11} - T_4$) × 0.24*

(97) = *Item* 95 + *Item* 96

(98) = $\frac{Item\ 81 - Item\ 24}{100} \times 14600$

(99) = $\frac{W \times (T_{14} - T_{13})}{Item\ 70\ (\text{or } 71)}$

This item can be determined only in plants where ash and refuse are discharged into water.

(100) = $\frac{CO}{CO_2 + CO} \times Item\ 83 \times 10160$ (Use data from *Item* 37)

(101) = (*Item* 40 − *Item* 44) × ($T_{11} - T_4$) × 0.24 + (*Item* 46 × 0.455)

(102) = $(T_6 - T_{11}) \times \left\{ Item\ 44 \times 0.24 + \left[(Item\ 44 - Item\ 83) \times Item\ 46 + \frac{Item\ 25 + 9 \times Item\ 31}{100} \right] \times 0.455 \right\}$

(103) = (*Item* 40 − *Item* 44) × ($T_6 - T_{11}$) × (0.24 + *Item* 46 × 0.455)

(104) = (*Item* 41 − *Item* 40) × ($T_6 - T_1$) × (0.24 + *Item* 46 × 0.455)

(105) = *Item* 92 − Sum of *Items* 93, 95, 96, and 98 to 104, inclusive

*NOTE—*Items* 96, 101, 102, 103 and 104. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

NOTE—*Items* 95, 102 and 104. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 3*b* HEAT BALANCE OF STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, AND ECONOMIZER. SOLID FUELS

Item	HEAT VALUES	B.t.u.	Per cent
(92)	= Heat per lb. coal as fired (high heating value)	....	
(93)	= Heat absorbed by water and steam in boiler and superheater	....	....
(94)	= Heat absorbed by steam in superheater	....	....
(95)	= Heat absorbed by water in economizer	....	....
	UNAVOIDABLE LOSSES		
(96)	= Heat loss due to moisture in coal, moisture accompanying theoretical air, and water from combustion of hydrogen, up to T_{10}	....	....
(97)	= Heat loss due to theoretical dry gases, T_4 to T_{10}	....	....
(98)	= Total unavoidable losses	....	....
	OTHER LOSSES		
(99)	= Heat loss due to combustible in refuse	....	....

		B.t.u.	Per cent
(100)	= Heat loss due to sensible heat in refuse, cinders, and soot	....	....
(101)	= Heat loss due to unburned gaseous combustibles	....	....
(102)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{10}	....	....
(103)	= Heat loss due to theoretical dry gases, moisture in coal, moisture accompanying theoretical air and water from combustion of hydrogen, T_{10} to T_7	....	....
(104)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_{10} to T_7	....	....
(105)	= Heat loss due to air and moisture leaking through boiler setting, T_1 to T_7	....	....
(106)	= Heat loss due to air and moisture leaking through economizer setting, T_1 to T_7	....	....
(107)	= Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....
	ECONOMIZER		
(108)	= Heat available to economizer in flue gases including moisture from T_6 to T_{10}		
(109)	= Efficiency of economizer	....	....

TABLE 3*d* HEAT-BALANCE COMPUTATIONS FOR A STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, AND ECONOMIZER. SOLID FUELS

Item

(92) = *Item* 26 (or 27)

(93) = *Item* 85 (or 86) × 970.4

(94) = $(H_1 - H) \times$ *Item* 84

(95) = $(h - h_1) \times$ *Item* 84

(96) = $(1090.7 + 0.455T_{10} - T_{12}) \times \left(\frac{\textit{Item } 25 + 9 \times \textit{Item } 31}{100}\right) +$ (*Item* 44 − *Item* 83) × *Item* 46 × 0.455 × ($T_{10} - T_4$)

(97) = *Item* 44 × ($T_{10} - T_4$) × 0.24*

(98) = *Item* 96 + *Item* 97

(99) = $\frac{(\textit{Item } 81 - \textit{Item } 24) \times 14600}{100}$

(100) = $\frac{W \times (T_{14} - T_{13})}{\textit{Item } 70 \text{ (or } 71)}$

This item can be determined only in plants where ash and refuse are discharged into water.

(101) = $\frac{CO}{CO_2 + CO} \times$ *Item* 83 × 10,160. (Use data from Item 38.)

(102) = (*Item* 40 − *Item* 44) × ($T_{10} - T_4$) × (0.24 + *Item* 46 × 0.455)

(103) = $(T_7 - T_{10}) \times \left\{ \textit{Item } 44 \times 0.24 + \left[(\textit{Item } 44 - \textit{Item } 83) \times \textit{Item } 46 + \frac{\textit{Item } 25 + 9 \times \textit{Item } 31}{100} \right] \times 0.455 \right\}$

(104) = (*Item* 40 − *Item* 44) × ($T_7 - T_{10}$) × (0.24 + *Item* 46 × 0.455)

(105) = (*Item* 41 − *Item* 40) × ($T_7 - T_1$) × (0.24 + *Item* 46 × 0.455)

(106) = (*Item* 42 − *Item* 41) × ($T_7 - T_1$) × (0.24 + *Item* 46 × 0.455)

(107) = *Item* 92 − Sum of *Items* 93, 95 to 97 and 99 to 106, inclusive

(108) = $(T_6 - T_{10}) \times \left\{ \textit{Item } 41 \times 0.24 + \left[(\textit{Item } 41 - \textit{Item } 83) \times \textit{Item } 46 + \frac{\textit{Item } 25 + 9 \times \textit{Item } 31}{100} \right] \times 0.455 \right\}$

(109) = $\frac{\textit{Item } 95}{\textit{Item } 108}$

*NOTE—*Items* 97, 102, 103, 104, 105, 106, 107, 108. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

*NOTE—*Items* 96, 103, 105, 106 and 108. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 4*b* HEAT BALANCE OF STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, ECONOMIZER, AND AIR HEATER. SOLID FUELS

Item		B.t.u.	Per cent
	HEAT VALUES		
(92)	Heat per lb. coal (as fired, dry) (high heating value)	....	....
(93)	Heat absorbed by water and steam in boiler and superheater	....	....
(94)	Heat absorbed by steam in superheater	....	....
(95)	Heat absorbed by water in economizer	....	....
	LOSSES		
(96)	Heat loss due to combustible in refuse	....	....
(97)	Heat loss due to sensible heat in refuse	....	....
(98)	Heat loss due to incomplete combustion of carbon	....	....
(99)	Heat loss due to theoretical dry gases, T_2 to T_8	....	....
(100)	Heat loss due to moisture in coal, moisture accompanying theoretical air, and water from combustion of hydrogen, up to T_8	....	....
(101)	Heat loss due to excess air and accompanying moisture entering furnace, T_2 to T_8	....	....
(102)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_8	....	....
(103)	Heat loss due to air and moisture leaking through economizer setting, T_1 to T_8	....	....
(104)	Heat loss due to air and moisture leaking through air heater setting, T_1 to T_8	....	....
(105)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for		
	ECONOMIZER		
(106)	Heat available to economizer in flue gases including moisture, T_6 to T_{10}		
(107)	Efficiency of economizer		
	AIR HEATER		
(108)	Heat available to air heater in flue gases including moisture, T_2 to T_2		
(109)	Heat absorbed by air heater		
(110)	Efficiency of air heater		

NOTE—If unit does not include economizer do not fill out Items 95, 103, 106 and 107. If data are available for further segregation of losses, other items may be added.

TABLE 4*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, ECONOMIZER, AND AIR HEATER. SOLID FUELS

Item

(92) = *Item* 26 (or 27)

(93) = *Item* 85 (or 86) × 970.4

(94) = $(H_1 - H) \times$ *Item* 84

(95) = $(h - h_1) \times$ *Item* 84

(96) = $\frac{(\textit{Item } 81 - \textit{Item } 24) \times 14600}{100}$

(97) = $\frac{W(T_{14} - T_{13})}{\textit{Item } 70 \text{ (or } 71)}$

This item can be determined only in plants where ash and refuse are discharged into water.

(98) = $\frac{CO}{CO_2 + CO} \times$ *Item* 83 × 10160

(99) = *Item* 44 × ($T_8 - T_2$) × 0.24*

(100) = $(1090.7 + 0.455T_8 - T_{12}) \times \frac{\textit{Item } 25 + 9 \times \textit{Item } 31}{100} +$ (*Item* 44 − *Item* 83) × *Item* 46 × 0.455 × ($T_8 - T_2$)

(101) = (*Item* 40 − *Item* 44) × ($T_8 - T_2$) × (0.24 + *Item* 46 × 0.455)

(102) = (*Item* 41 − *Item* 40) × ($T_8 - T_1$) × (0.24 + *Item* 46 × 0.455)

(103) = (*Item* 42 − *Item* 41) × ($T_8 - T_1$) × (0.24 + *Item* 46 × 0.455)

(104) = (*Item* 43 − *Item* 42) × ($T_8 - T_1$) × (0.24 + *Item* 46 × 0.455)

(105) = *Item* 92 − The sum of *Items* 93, 95 to 104, inclusive, and *Item* 109

(106) = $(T_6 - T_{10}) \times \left\{ \textit{Item } 41 \times 0.24 + \left[(\textit{Item } 41 - \textit{Item } 83) \times \textit{Item } 46 + \frac{\textit{Item } 25 + 9 \times \textit{Item } 31}{100} \right] \times 0.455 \right\}$

(107) = $\frac{\textit{Item } 95}{\textit{Item } 106}$

(108) = $(T_2 - T_2) \times \left\{ \textit{Item } 42 \times 0.24 + \left[(\textit{Item } 42 - \textit{Item } 83) \times \textit{Item } 46 + \frac{\textit{Item } 25 + 9 \times \textit{Item } 31}{100} \right] \times 0.455 \right\}$

(109) = ($T_8 - T_2$) × *Item* 45 × (0.24 + *Item* 46 × 0.455)

(110) = $\frac{\textit{Item } 109}{\textit{Item } 108}$

*NOTE—*Items* 99, 101, 102, 103, 104, 108 and 109. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

NOTE—*Items* 100, 102, 103, 104, 106, 108, and 109. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 5a DATA AND RESULTS, TEST OF STATIONARY STEAM-GENERATING UNIT. LIQUID FUELS—AS FIRED—MOISTURE FREE

GENERAL INFORMATION

(1) Date of test
(2) Location of plant
(3) Owner of plant
(4) Maker and type of boiler
(5) Maker and type of superheater
(6) Maker and type of economizer
(7) Maker and type of air heater
(8) Maker and type of fuel-burning equipment
(9) Test conducted by
(10) Object of test

DESCRIPTION, DIMENSIONS, ETC.

(11) Boiler heating surface ..... sq. ft.
(12) Superheater surface ..... sq. ft.
(13) Economizer surface ..... sq. ft.
(14) Air-heater surface ..... sq. ft.
(15) Number of burners
(16) Draft
(17) Fuel
(18) Area of furnace floor ..... wide ..... deep ..... sq. ft.
(19) Height of furnace floor to nearest heating surface ..... ft.
(20) Furnace volume per sq. ft. boiler heating surface ..... cu. ft.

FUEL AND GAS ANALYSES AND DATA

Fuel—As Fired—Moisture-Free

(21) Moisture ..... per cent
(22) B.t.u. per lb. as fired ..... B.t.u.
(23) B.t.u. per lb. moisture free ..... B.t.u.
(24) Flash point ..... deg. fahr.
(25) Carbon ..... per cent
(26) Hydrogen ..... per cent
(27) Oxygen ..... per cent
(28) Nitrogen ..... per cent
(29) Baumé gravity ..... deg.

Gas

(30) Gas analysis, furnace:
Per cent CO_2 ... O_2 ... CO ... N_2 ... SO_2 ...
(31) Gas analysis, boiler outlet:
Per cent CO_2 ... O_2 ... CO ... N_2 ... SO_2 ...
(32) Gas analysis, economizer outlet:
Per cent CO_2 ... O_2 ... CO ... N_2 ... SO_2 ...
(33) Gas analysis, air-heater outlet:
Per cent CO_2 ... O_2 ... CO ... N_2 ... SO_2 ...
(34) Dry gas per lb. fuel, furnace (as fired, moisture free) ..... lb.
(35) Dry gas per lb. fuel, boiler outlet (as fired, moisture free) ..... lb.
(36) Dry gas per lb. fuel, economizer outlet (as fired, moisture free) ..... lb.
(37) Dry gas per lb. fuel, air heater outlet (as fired, moisture free) ..... lb.
(38) Dry gas per lb. fuel, theoretical (as fired, moisture free) ..... lb.
(39) Air supplied per lb. fuel furnace (as fired, moisture free) ..... lb.

Pressures and Drafts

(40) Moisture in air ..... lb. per lb. air
(41) Steam pressure by gage, boiler ..... lb. per sq. in.
(42) Steam pressure by gage, superheater outlet ..... lb. per sq. in.
(43) Pressure of fuel at burners ..... lb. per sq. in.
(44) Pressure of air for combustion at burners ..... in. of water
(45) Draft in furnace ..... in. of water
(46) Draft at boiler outlet ..... in. of water
(47) Draft at economizer outlet ..... in. of water
(48) Draft at air-heater outlet ..... in. of water

Temperatures

(49) Steam temperature ..... deg. fahr.
(50) Moisture in steam ..... per cent
(51) Superheat ..... deg. fahr.
(52) Temperature of air surrounding boiler, T_1 ..... deg. fahr.
(53) Temperature of air entering air heater, T_2 ..... deg. fahr.
(54) Temperature of air leaving air heater, T_3 ..... deg. fahr.
(55) Temperature of air for combustion, T_4 ..... deg. fahr.
(56) Temperature of furnace, T_5 ..... deg. fahr.
(57) Temperature of gases leaving boiler, T_6 ..... deg. fahr.
(58) Temperature of gases leaving economizer, T_7 ..... deg. fahr.
(59) Temperature of gases leaving air heater, T_8 ..... deg. fahr.
(60) Temperature of feedwater entering boiler, T_9 ..... deg. fahr
(61) Temperature of feedwater entering economizer, T_{10} ..... deg. fahr
(62) Temperature of water in boiler at point where gases leave boiler, T_{11} ..... deg. fahr.
(63) Temperature of fuel at burner, T_{12} ..... deg. fahr.

Hourly Quantities

(64) Duration of test ..... hr.
(65) Fuel as fired per hour ..... lb.
(66) Fuel per hour, moisture free ..... lb.
(67) Fuel per cu. ft. furnace volume per hour, as fired ..... lb.
(68) Fuel per burner, per hour as fired, moisture free ..... lb
(69) Fuel per burner, per hour, moisture free ..... lb.
(70) Fuel per cu. ft. furnace volume, moisture free ..... lb.
(71) Actual water per hour ..... lb.
(72) Factor of evaporation
(73) Equivalent water per hour ..... lb.
(73a) Boiler horsepower, average ..... hp.

Evaporation

(74) Actual evaporation per lb. fuel, as fired, moisture free ..... lb.
(75) Equivalent evaporation per lb. fuel, as fired ..... lb.
(76) Equivalent evaporation per lb. fuel, moisture free ..... lb.
(77) Equivalent evaporation per sq. ft. heating surface per hour ..... lb.

Horsepower

(78) Number of 1000 B.t.u. absorbed per sq. ft. of boiler heating surface per hour ..... B.t.u.
(79) Per cent rating ..... per cent

Efficiency

(80) Efficiency of boiler, superheater, furnace, burners, and air heater ..... per cent
(81) Efficiency including economizer ..... per cent

TABLE 5b HEAT BALANCE OF A STEAM-GENERATING UNIT, SHORT FORM. LIQUID FUELS

Item		B.t.u.	Per cent
(82)	Heat absorbed by water and steam in boiler and superheater		
(83)	Heat absorbed by water in economizer		
(84)	Heat loss due to moisture in fuel		
(85)	Heat loss due to water from combustion of hydrogen		
(86)	Heat loss due to moisture in air		
(87)	Heat loss due to dry chimney gases		
(88)	Heat loss due to incomplete combustion of carbon		
(89)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for		

TABLE 5c COMPUTATIONS FOR TEST OF STATIONARY STEAM-GENERATING UNIT. LIQUID FUEL

EXPLANATION OF SYMBOLS

Wherever CO_2, O_2, CO, and N_2 are used they are the percentages by volume of these constituents in the gases of combustion.

H = total heat (in B.t.u. per lb.) of saturated steam at the boiler outlet pressure
H_1 = total heat (in B.t.u. per lb.) of superheated steam at the superheater outlet pressure
h = total heat (in B.t.u. per lb.) in feedwater at boiler inlet
h_1 = total heat (in B.t.u. per lb.) in feedwater at economizer inlet
L = latent heat (in B.t.u. per lb.) in steam at pressure in steam main
t_2 = temperature of steam after expansion in calorimeter.

GENERAL

If test is on a moisture-free basis, draw a line through "as fired" wherever the words "as fired dry" appear together and vice versa. Whichever basis is chosen must be followed throughout. Percentage results in heat balance will be the same in either case.

Items 11 to 14—Heating surface shall consist of that portion of the surface of the heat-transfer apparatus exposed to both the gases being cooled and the fluid being heated at the same time (computed on the gas side).

Item 16—State whether natural, forced, induced or a combination of one or more kinds of draft is employed.

Item 17—State general class of fuel, give district where produced.

Item 20—Furnace volume is the cubic space provided for the combustion of fuel before the products of combustion pass through any heating surface.

Items 21 to 29 – As-fired-analysis items =

$$\text{dry-analysis items} \times \left(1 - \frac{\textit{Item } 21}{100}\right)$$

Items 34 to 37 $= \dfrac{11\,CO_2 + 8\,O_2 + 7(CO + N_2)}{3(CO_2 + CO)} \times \textit{Item } 83$

Use data from Items 30 to 33.

$$\textit{Item } 38 = \frac{12.52 \times \textit{Item } 25 + 26.56 \times \textit{Item } 26 + \textit{Item } 28}{100}$$

$$\textit{Item } 39 = \textit{Item } 34 + \frac{9 \times \textit{Item } 26}{100} - .1$$

Item 40—For methods of determination see code on Instruments and Apparatus, Par. —.

Item 50—Either determine from charts or the following formula:

$$100 \times \frac{H - 1150.4 - 0.47 \times (t_2 - 212)}{L}$$

$$\textit{Item } 72 \quad \text{(For saturated or wet steam)} = \frac{H - \dfrac{L \times \textit{Item } 55}{100}}{970.4} - h$$

$$\text{(For superheated steam)} = \frac{H_1 - h}{970.4}$$

$$\textit{Item } 73 = \textit{Item } 71 \times \textit{Item } 72$$

$$\textit{Item } 73a = \frac{\textit{Item } 73}{34.5}$$

$$\textit{Item } 74 = \frac{\textit{Item } 71}{\textit{Item } 65 \text{ (or } 66)}$$

$$\textit{Item } 75 = \frac{\textit{Item } 73}{\textit{Item } 65}$$

$$\textit{Item } 76 = \frac{\textit{Item } 73}{\textit{Item } 66}$$

$$\textit{Item } 77 = \frac{\textit{Item } 73}{\textit{Item } 11}$$

$$\textit{Item } 78 = \frac{\textit{Item } 73 \times 970.4}{\textit{Item } 11}$$

$$\textit{Item } 79 = \frac{\textit{Item } 73a \times 10}{\textit{Item } 11}$$

$$\textit{Item } 80 = \frac{\textit{Item } 75 \text{ (or } 76) \times 970.4}{\textit{Item } 22 \text{ (or } 23)}$$

$$\textit{Item } 81 = \frac{\textit{Item } 75 \text{ (or } 76) \times 970.4 + (h - h_{11}) \times \textit{Item } 74}{\textit{Item } 22 \text{ (or } 23)}$$

TABLE 5*b*. HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT—SHORT FORM. LIQUID FUELS

Item

(82) = *Item* 75 (or 76) × 970.4

(83) = $(h - h_{11}) \times$ *Item* 74

(84) = $\frac{\textit{Item } 21}{100} \times (1090.7 + 0.455\ T_8 - T_{12})$

(85) = $\frac{\textit{Item } 26 \times 9}{100} \times (1090.7 + 0.455\ T_8 - T_{12})$

If economizer is installed without air heater, substitute T_7 for T_8. If air heater is installed, substitute T_8 for T_8 in Items 84, 85, 86, and 87.

(86) = *Item* 39 × *Item* 40 × 0.455 × $(T_8 - T_4)$.

This item is small and is frequently included in Item 89.

(87) = *Item* 35 (or 36 or 37) × 0.24 × $(T_8 - T_{11})$.

If boiler and superheater use Item 35, if economizer use Item 36, if air heater use Item 37.

(88) = $\frac{CO}{CO_2 + CO} \times$ *Item* 25 × 10160.

(89) = *Item* 22 (or 23) − Sum of *Items* 82 to 88, inclusive.

TABLE 6*b* HEAT BALANCE OF STEAM-GENERATING UNIT COMPRISING BOILER AND SUPERHEATER, WITH OR WITHOUT INTEGRAL ECONOMIZER. LIQUID FUELS

Item	HEAT VALUES	B.t.u.	Per cent
(82)	= Heat per lb. fuel as fired (high heating value)	....	....
(83)	= Heat absorbed by water and steam in boiler and superheater	....	....
(84)	= Heat absorbed by steam in superheater	....	....
	UNAVOIDABLE LOSSES		
(85)	= Heat loss due to moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, up to T_{11}	....	....
(86)	= Heat loss due to theoretical dry gases, T_4 to T_{11}	....	....
(87)	= Total unavoidable losses	....	....
	OTHER LOSSES		
(88)	= Heat loss due to incomplete combustion of carbon	....	....
(89)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{11}	....	....
(90)	= Heat loss due to theoretical dry gases, moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, T_{11} to T_8	....	....
(91)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_{11} to T_8	....	....
(92)	= Heat loss due to air and moisture leaking through boiler setting, T_1 to T_8	....	....
(93)	= Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....

TABLE 6*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT COMPRISING BOILER AND SUPERHEATER, WITH OR WITHOUT INTEGRAL ECONOMIZER. LIQUID FUELS

Item

(82) = *Item* 22 (or 23)

(83) = *Item* 75 (or 76) × 970.4

(84) = $(H_1 - H) \times$ *Item* 74

(85) = $(1090.7 + 0.455\ T_{11} - T_{12}) \times \frac{(\textit{Item } 21 + 9 \times \textit{Item } 26)}{100} +$ (*Item* 38 − *Item* 25) × *Item* 40 × 0.455 × $(T_{11} - T_4)$

(86) = *Item* 38 × $(T_{11} - T_4) \times 0.24$*

(87) = *Item* 85 + *Item* 86

(88) = $\frac{CO}{CO_2 + CO} \times$ *Item* 25 × 10160. (Use data from Item 31.)

(89) = (*Item* 34 − *Item* 38) × $(T_{11} - T_4) \times (0.24 +$ *Item* 40 × 0.455)

(90) = $(T_8 - T_{11}) \times \left\{ \textit{Item } 38 \times 0.24 + \left[(\textit{Item } 38 - \textit{Item } 25) \times \textit{Item } 40 + \frac{\textit{Item } 21 + 9 \times \textit{Item } 26}{100} \right] \times 0.455 \right\}$

(91) = (*Item* 34 − *Item* 38) × $(T_{11} - T_8) \times (0.24 +$ *Item* 40 × 0.455)

(92) = (*Item* 35 − *Item* 34) × $(T_8 - T_{11}) \times (0.24 +$ *Item* 40 × 0.455)

(93) = *Item* 82 − Sum of *Items* 83, 85, 86 and 88 to 92 inclusive.

* NOTE—*Items* 86, 89, 90, 91, 92. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

NOTE—*Items* 85, 89, 90, 91 and 92. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 7*b* HEAT BALANCE OF A STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, AND ECONOMIZER. LIQUID FUELS

Item	HEAT VALUES	B.t.u.	Per cent
(82)	Heat per lb. fuel, as fired (higher heating value)	....	....
(83)	Heat absorbed by water and steam in boiler and superheater	....	....
(84)	Heat absorbed by steam in superheater	....	....
(85)	Heat absorbed by water in economizer	....	....
	UNAVOIDABLE LOSSES		
(86)	Heat loss due to moisture in fuel, moisture accompanying theoretical air from combustion of hydrogen, up to T_{10}	....	....
(87)	Heat loss due to theoretical dry gases, T_4 to T_{10}	....	....
(88)	Total unavoidable losses	....	....
	OTHER LOSSES		
(89)	Heat loss due to incomplete combustion of carbon	....	....
(90)	Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{10}	....	....
(91)	Heat loss due to theoretical dry gases, moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, T_{10} to T_7	....	....
(92)	Heat loss due to excess air entering furnace and moisture accompanying same, T_{10} to T_7	....	....
(93)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_7	....	....
(94)	Heat loss due to air and moisture leaking through economizer setting, T_1 to T_7	....	....
(95)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiations and unaccounted for	....	....
	ECONOMIZER		
(96)	Heat available to economizer in flue gases, including moisture, T_8 to T_{10}	....	....
(97)	Efficiency of economizer	....	....

TABLE 7*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, AND ECONOMIZER. LIQUID FUELS

Item

(82) = *Item* 22 (or 23)

(83) = *Item* 75 (or 76) × 970.4

(84) = $(H_1 - H) \times$ *Item* 74

(85) = $(h - h_1) \times$ *Item* 74

(86) = $(1090.7 + 0.455\ T_{10} - T_{12}) \times \left(\frac{\textit{Item } 21 + 9 \times \textit{Item } 26}{100} \right) +$ (Item 38 − *Item* 25) × *Item* 40 × 0.455 × $(T_{10} - T_4)$

(87) = *Item* 38 × $(T_{10} - T_4) \times 0.24$*

(88) = *Item* 86 + *Item* 87

(89) = $\frac{CO}{CO_2 + CO} \times$ *Item* 25 × 10160. (Use data from Item 31)

(90) = (*Item* 34 − *Item* 38) × $(T_{10} - T_4) \times (0.24 +$ *Item* 40 × 0.455)

(91) = $(T_7 - T_{10}) \times \left\{ \textit{Item } 38 \times 0.24 + \left[(\textit{Item } 38 - \textit{Item } 25) \times \textit{Item } 40 + \frac{\textit{Item } 21 + 9 \times \textit{Item } 26}{100} \right] \times 0.455 \right\}$

(92) = (*Item* 34 − *Item* 38) × $(T_7 - T_{10}) \times (0.24 +$ *Item* 40 × 0.455)

(93) = (*Item* 35 − *Item* 34) × $(T_7 - T_{10}) \times (0.24 +$ *Item* 40 × 0.455)

(94) = (*Item* 36 − *Item* 35) × $(T_7 - T_{10}) \times (0.24 +$ *Item* 40 × 0.455)

(95) = *Item* 82 − Sum of *Items* 83, 85 to 94, inclusive.

(96) = $(T_6 - T_{10}) \times \left\{ Item\ 35 \times 0.24 + \left[(Item\ 35 - Item\ 25) \times Item\ 40 + \frac{Item\ 21 + 9 \times Item\ 26}{100} \right] \times 0.455 \right\}$

(97) = $\frac{Item\ 85}{Item\ 96}$

* NOTE—*Items* 87, 90, 91, 92, 93, 94 and 96. 0.24 is the value in common use for the specific heat of dry gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

NOTE—*Items* 86, 90, 91, 92, 93, 94 and 96. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 8*b* HEAT BALANCE OF A STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, ECONOMIZER AND AIR HEATER. LIQUID FUELS

Item	HEAT VALUES	B.t.u.	Per cent
(82)	Heat per lb. fuel, as fired (higher heating value)		
(83)	Heat absorbed by water and steam in boiler and superheater		
(84)	Heat absorbed by steam in superheater		
(85)	Heat absorbed by water in economizer		
	LOSSES		
(86)	Heat loss due to incomplete combustion of carbon		
(87)	Heat loss due to theoretical dry gases, T_2 to T_8		
(88)	Heat loss due to moisture in fuel, moisture accompanying theoretical air and water from the combustion of hydrogen, up to T_8		
(89)	Heat loss due to excess air entering furnace and moisture accompanying same, T_2 to T_8		
(90)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_8		
(91)	Heat loss due to air and moisture leaking through economizer setting, T_1 to T_8		
(92)	Heat loss due to air and moisture leaking through air heater setting, T_1 to T_8		
(93)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for		
	ECONOMIZER		
(94)	Heat available to economizer in flue gases, including moisture, T_7 to T_2		
(95)	Efficiency of economizer		
	AIR HEATER		
(96)	Heat available to air heater in flue gases, including moisture, T_7 to T_2		
(97)	Heat absorbed by air heater		
(98)	Efficiency of air heater		

NOTE—If unit does not include economizer do not fill out Items 85, 91, 94, 95. If data are available for further segregation of losses, other items may be added.

TABLE 8*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, ECONOMIZER, AND AIR HEATER. LIQUID FUELS

Item

(82) = *Item* 22 (or 23)

(83) = *Item* 75 (or 76) × 970.4

(84) = $(H_1 - H) \times Item\ 74$

(85) = $(h - h_{11}) \times Item\ 74$

(86) = $\frac{CO}{CO_2 + CO} \times Item\ 25 \times 10160$

(87) = $Item\ 38 \times (T_8 - T_2) \times 0.24$*

(88) = $(1090.7 + 0.455\ T_8 - T_{12}) \times \left(\frac{(Item\ 21 + 9 \times Item\ 26)}{100} \right) + (Item\ 38 - Item\ 25) \times Item\ 40 \times 0.455 \times (T_8 - T_2)$

(89) = $(Item\ 34 - Item\ 38) \times (T_8 - T_2) \times (0.24 + Item\ 40 \times 0.455)$

(90) = $(Item\ 35 - Item\ 34) \times (T_8 - T_1) \times (0.24 + Item\ 40 \times 0.455)$

(91) = $(Item\ 36 - Item\ 35) \times (T_8 - T_1) \times (0.24 + Item\ 40 \times 0.455)$

(92) = $(Item\ 37 - Item\ 36) \times (T_8 - T_1) \times (0.24 + Item\ 40 \times 0.455)$

(93) = *Item* 82 − Sum of *Items* 83, 85 to 92, inclusive, and *Item* 97.

(94) = $(T_6 - T_{10}) \times \left\{ Item\ 35 \times 0.24 + \left[(Item\ 35 - Item\ 25) \times Item\ 40 + \frac{Item\ 21 + 9 \times Item\ 26}{100} \right] \times 0.455 \right\}$

(95) = $\frac{Item\ 85}{Item\ 94}$

(96) = $(T_7 - T_2) \times \left\{ Item\ 36 \times 0.24 + \left[(Item\ 36 - Item\ 25) \times Item\ 40 + \frac{Item\ 21 + 9 \times Item\ 26}{100} \right] \times 0.455 \right\}$

(97) = $(T_3 - T_2) \times Item\ 39 \times (0.24 + Item\ 40 \times 0.455)$

(98) = $\frac{Item\ 97}{Item\ 96}$

* NOTE—*Items* 87, 89, 90, 91, 92, 93, 94, and 96. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

NOTE—*Items* 88, 89, 90, 91, 92, 93, 94, 96, 97. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 9*a* DATA AND RESULTS OF TEST OF STATIONARY STEAM-GENERATING UNIT. GASEOUS FUELS

	GENERAL INFORMATION	
(1)	Date of test	
(2)	Location of plant	
(3)	Owner of plant	
(4)	Maker and type of boiler	
(5)	Maker and type of superheater	
(6)	Maker and type of economizer	
(7)	Maker and type of air heater	
(8)	Maker and type of fuel-burning equipment	
(9)	Test conducted by	
(10)	Object of test	
	DESCRIPTION DIMENSIONS, ETC.	
(11)	Boiler heating surface	sq. ft.
(12)	Superheater surface	sq. ft.
(13)	Economizer surface	sq. ft.
(14)	Air heater surface	sq. ft.
(15)	Number of burners	
(16)	Draft	
(17)	Fuel	
(18)	Area of furnace floor ..... Wide ..... Deep	sq. ft.
(19)	Height of furnace, floor to nearest heating surface	ft.
(20)	Furnace volume per sq. ft. of boiler heating surface	cu. ft.

FUEL AND COMBUSTION PRODUCTS AND DATA

Fuel Analysis

(21)	Moisture	volume	per cent	weight
(22)	Carbon monoxide, CO	volume	per cent	weight
(23)	Hydrogen, H_2	volume	per cent	weight
(24)	Methane, CH_4	volume	per cent	weight
(25)	Acetylene, C_2H_2	volume	per cent	weight
(26)	Ethylene, C_2H_4	volume	per cent	weight
(27)	Ethane, C_2H_6	volume	per cent	weight
(28)	Hydrogen sulphide, H_2S	volume	per cent	weight
(29)	Oxygen, O_2	volume	per cent	weight
(30)	Nitrogen, N_2	volume	per cent	weight
(31)	Carbon dioxide, CO_2	volume	per cent	weight
(32)	B.t.u. per cu. ft. standard conditions			B.t.u.
(33)	B.t.u. per lb.			B.t.u.
(34)	Weight per cu. ft. standard conditions			lb.

Combustion Products

(35) Gas analysis, furnace:
Per cent CO_2 ... O_2 ... CO ... N_2 ... SO_2

(36) Gas analysis, boiler outlet:
Per cent CO_2 ... O_2 ... CO ... N_2 ... SO_2

(37) Gas analysis, economizer:
Per cent CO_2 ... O_2 ... CO ... N_2 ... SO_2

(38) Gas analysis, air heater:
Per cent CO_2 ... O_2 ... CO ... N_2 ... SO_2

(39) Dry gas per lb. fuel, furnace ... lb.
(40) Dry gas per lb. fuel, boiler outlet ... lb.
(41) Dry gas per lb. fuel, economizer outlet ... lb.
(42) Dry gas per lb. fuel, air-heater, outlet ... lb.
(43) Dry gas per lb. fuel, theoretical ... lb.
(44) Air supplied per lb. fuel, furnace ... lb.

Pressures and Drafts

(45) Moisture in air ... lb. per lb. air
(46) Steam pressure by gage, boiler ... lb. per sq. in.
(47) Steam pressure by gage, superheater ... lb. per sq. in.
(48) Pressure of fuel at burners ... in. of water
(49) Pressure of air for combustion at burners ... in. of water
(50) Draft in furnace ... in. of water
(51) Draft at boiler outlet ... in. of water
(52) Draft at economizer outlet ... in. of water
(53) Draft at air-heater outlet ... in. of water

Temperatures

(54)	Steam temperature	deg. fahr.
(55)	Moisture in steam	per cent
(56)	Superheat	deg. fahr.
(57)	Temperature of air surrounding boiler, T_1	deg. fahr.
(58)	Temperature of air entering air heater, T_2	deg. fahr.
(59)	Temperature of air leaving air heater, T_3	deg. fahr.
(60)	Temperature of air for combustion, T_4	deg. fahr.
(61)	Temperature of furnace, T_5	deg. fahr.
(62)	Temperature of gases leaving boiler, T_6	deg. fahr.
(63)	Temperature of gases leaving economizer, T_7	deg. fahr.
(64)	Temperature of gases leaving air heater, T_8	deg. fahr.
(65)	Temperature of feedwater entering boiler, T_9	deg. fahr.
(66)	Temperature of feedwater entering economizer, T_{10}	deg. fahr.
(67)	Temperature of water in boiler at point where gases leave boiler, T_{11}	deg. fahr.
(68)	Temperature of fuel at burner, T_{12}	deg. fahr.

Hourly Quantities

(69)	Duration of test	hr.
(70)	Fuel gas as fired per hour	lb.
(71)	Fuel gas per hour, standard conditions	cu. ft.
(72)	Fuel gas per burner per hour	lb.
(73)	Fuel gas per cu. ft. of furnace volume, per hour	lb.
(74)	Actual water per hour	lb.
(75)	Factor of evaporation	
(76)	Equivalent water per hour	lb.
(76a)	Boiler horsepower, average	
(77)	Actual evaporation per lb. fuel	lb.
(78)	Equivalent evaporation per lb. fuel	lb.
(79)	Equivalent evaporation per sq. ft. boiler heating surface per hour	lb.

Horsepower

(80)	Number of 1000 B.t.u. absorbed per sq. ft. of boiler heating surface per hour	B.t.u.
(81)	Per cent rating	per cent

Efficiency

(82)	Efficiency of boiler, superheater, furnace, burners, and air heater	per cent
(83)	Efficiency including economizer	per cent

TABLE 9*b* HEAT BALANCE OF A STEAM-GENERATING UNIT. SHORT FORM. GASEOUS FUELS

Item		B.t.u.	Per cent
(84)	Heat absorbed by water and steam in boiler and superheater		
(85)	Heat absorbed by water in economizer		
(86)	Heat loss due to moisture in fuel		
(87)	Heat loss due to water from combustion of hydrogen		
(88)	Heat loss due to moisture in air		
(89)	Heat loss due to dry chimney gases		
(90)	Heat loss due to incomplete combustion of carbon		
(91)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation and unaccounted for		

TABLE 9*c* COMPUTATIONS FOR TEST OF STATIONARY STEAM-GENERATING UNIT. GASEOUS FUEL

EXPLANATION OF SYMBOLS

Wherever CO_2, O_2, CO, and N_2 are used they are the percentages by volume of these constituents in the gases of combustion.

C = carbon content per lb. of fuel gas.

H = total heat (in B.t.u. per lb.) of saturated steam at the boiler outlet pressure.

H_1 = total heat (in B.t.u. per lb.) of superheated steam at the superheater outlet pressure.

h = total heat (in B.t.u. per lb.) in feedwater at boiler inlet.

h_1 = total heat (in B.t.u. per lb.) in feedwater at economizer inlet.

L = latent heat (in B.t.u. per lb.) in steam at pressure in steam main.

t_2 = temperature of steam after expansion in calorimeter.

Item 11 to 14—Heating surface shall consist of that portion of the surface of the heat-transfer apparatus exposed to both the gases being cooled and the fluid being heated at the same time (computed on the gas side).

Item 16—State whether natural, forced, induced or a combination of one or more kinds of draft was employed.

Item 17—State general class of fuel, as blast-furnace gas, by-product coke-oven gas, natural gas, etc. and give district.

Item 20—Furnace volume is the cubic space provided for the combustion of fuel before the products of combustion pass through any heating surface.

Item 22 to 34—Fuel-gas analysis should be reported on dry basis. Where B.t.u. value is calculated it is on dry basis. Where determined on calorimeter should be corrected for moisture. If $T_{12} > T_1$ add mean specific heat $\times (T_{12} - T_1)$ to the calculated B.t.u. value. Standard conditions are 29.92 inches mercury and 32 deg. fahr.

Item 33 = *Item* 32 $\times$ *Item* 34.

$$\textit{Item 39 to 42} = \frac{11\,CO_2 + 8\,O_2 + 7(CO + N_2)}{3(CO_2 + CO)} \times \textit{Item 83}$$

Use data from Items 35 to 38. $C = {}^3/_7$ *Item* $22 + {}^3/_4$ *Item* $24 + {}^{12}/_{13}$ *Item* $25 + {}^6/_7$ *Item* $26 + {}^6/_7$ *Item* $27 + {}^3/_{11}$ *Item* 31 (by weight).

$$\textit{Item 43} = \frac{346 \times \textit{Item 22} + 26.56 \times \textit{Item 23} + 16.03 \times \textit{Item 24} + 13.60 \times \textit{Item 25} + 15.52 \times \textit{Item 26} + 15.33 \times \textit{Item 27} + 6.58 \times \textit{Item 28} + \textit{Item 30} + \textit{Item 31}}{100} \text{ (by weight)}$$

$$\textit{Item 44} = \textit{Item 39} + \frac{9 \times \textit{Item 23}}{100} - 1$$

Item 45—For methods of determination see code on Instruments and Apparatus Par. —.

Item 55—Determine either from charts or the following formula:

$$100 \times \frac{H - 1150.4 - 0.47 \times (t_2 - 212)}{L}$$

$$\textit{Item 75} \quad \text{(For saturated or wet steam)} = \frac{H - \frac{L \times \textit{Item 55}}{100} - h}{970.4}$$

$$\text{(For superheated steam)} = \frac{H_1 - h}{970.4}$$

$$\textit{Item 76} = \textit{Item 74} \times \textit{Item 75}$$

$$\textit{Item 76a} = \frac{\textit{Item 76}}{34.5}$$

$$\textit{Item 77} = \frac{\textit{Item 74}}{\textit{Item 70}}$$

$$\textit{Item 78} = \frac{\textit{Item 76}}{\textit{Item 70}}$$

$$\textit{Item 80} = \frac{\textit{Item 76} \times 970.4}{\textit{Item 11}}$$

$$\textit{Item 81} = \frac{\textit{Item 76a} \times 10}{\textit{Item 11}}$$

$$\textit{Item 79} = \frac{\textit{Item 76}}{\textit{Item 11}}$$

$$\textit{Item 80} = \frac{\textit{Item 76}}{34.5}$$

$$\textit{Item 81} = \frac{\textit{Item 80} \times 10}{\textit{Item 11}}$$

$$\textit{Item 82} = \frac{\textit{Item 78} \times 970.4}{\textit{Item 33}}$$

$$\textit{Item 83} = \frac{\textit{Item 78} \times 970.4 + (h - h_1) \times \textit{Item 77}}{\textit{Item 33}}$$

TABLE 9*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT. SHORT FORM—GASEOUS FUELS

Item

(84) = *Item* 78×970.4

(85) = $(h - h_1) \times$ *Item* 77

(86) = $\frac{\textit{Item 21}}{100} \times (1090.7 + 0.455\,T_6 - T_{12})$

(87) = $\frac{\textit{Item 23} \times 9}{100} \times (1090.7 + 0.455\,T_6 - T_{12})$

If economizer is installed without air heater, substitute T_7 for T_6. If air heater is installed, substitute T_8 for T_6 in Items 86, 87, 88 and 89.

(88) = *Item* $44 \times$ *Item* $45 \times 0.455\,(T_6 - T_4)$.
This item is small and is frequently included in Item 91.

(89) = *Item* 40(or 41 or 42) $\times 0.24 \times (T_6 - T_1)$.
If boiler and superheater use Item 40. If economizer use Item 41. If air heater use Item 42.

(90) = $\frac{CO}{CO_2 + CO} \times C \times 10160$

(91) = *Item* 33 − Sum of *Items* 84–90, inclusive.

TABLE 10*b* HEAT BALANCE OF STEAM-GENERATING UNIT COMPRISING BOILER AND SUPERHEATER, WITH OR WITHOUT INTEGRAL ECONOMIZER. GASEOUS FUELS

Item	HEAT VALUES	B.t.u.	Per cent
(84)	Heat per lb. fuel as fired (high heating value)	....	....
(85)	Heat absorbed by water and steam in boiler and superheater	....	....
(86)	Heat absorbed by steam in superheater	....	....
	UNAVOIDABLE LOSSES		
(87)	Heat loss due to moisture in fuel, moisture accompanying theoretical air and water from combustion of hydrogen, up to T_{11}	....	....
(88)	Heat loss due to theoretical dry gases, T_6 to T_{11}	....	....
(89)	Total unavoidable losses	....	....

	Other Losses	B.t.u.	Per cent
(90)	Heat loss due to incomplete combustion of carbon	....	....
(91)	Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{11}	....	....
(92)	Heat loss due to theoretical dry gases, moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, T_{11} to T_6	....	....
(93)	Heat loss due to excess air entering furnace and moisture accompanying same, T_{11} to T_6	....	....
(94)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_6	....	....
(95)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....

TABLE 10*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT COMPRISING BOILER AND SUPERHEATER, WITH OR WITHOUT INTEGRAL ECONOMIZER. GASEOUS FUELS

Item

(84) = *Item* 33

(85) = *Item* 78×970.4

(86) = $(H_1 - H) \times$ *Item* 77

(87) = $(1090.7 + 0.455T_{11} - T_{12}) \times \dfrac{(\textit{Item } 21 + 9 \times \textit{Item } 23)}{100} + (\textit{Item } 43 - C) \times \textit{Item } 43 \times 0.455 \times (T_{11} - T_4)$

(88) = $(\textit{Item } 43 \times T_{11} - T_4) \times 0.24$*

(89) = *Item* 87+*Item* 88

(90) = $\dfrac{CO}{CO_2 + CO} \times C \times 10160$. (Use data from Item 81)

(91) = $(\textit{Item } 39 - \textit{Item } 43) \times (T_{11} - T_4) \times (0.24 + \textit{Item } 45 \times 0.455)$.

(92) = $(T_6 - T_{11}) \times \left\{ \textit{Item } 43 \times 0.24 + \left[(\textit{Item } 43 - C) \times \textit{Item } 45 + \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100} \right] \times 0.455 \right\}$

(93) = $(\textit{Item } 39 - \textit{Item } 43) \times (T_{11} - T_6) \times (0.24 + \textit{Item } 45 \times 0.455)$

(94) = $(\textit{Item } 40 - \textit{Item } 39) \times (T_6 - T_1) \times (0.24 + \textit{Item } 45 \times 0.455)$

(95) = *Item* 84 − Sum of *Items* 85, 87, 88, and 90 to 94, inclusive.

* NOTE—*Items* 88, 91, 92, 93 and 94. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

NOTE—*Items* 87, 91, 92, 93 and 94. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 11*b* HEAT BALANCE OF A STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, AND ECONOMIZER. GASEOUS FUELS

Item	Heat Values	B.t.u.	Per cent
(84)	Heat per lb. fuel as fired (higher heating value)	....	....
(85)	Heat absorbed by water and steam in boiler and superheater	....	....
(86)	Heat absorbed by steam in superheater	....	....
(87)	Heat absorbed by water in economizer	....	....
	Unavoidable Losses		
(88)	Heat loss due to moisture in fuel, moisture accompanying theoretical air and water from combustion of hydrogen, up to T_{10}	....	....
(89)	Heat loss due to theoretically dry gases, T_4 to T_{10}	....	....
(90)	Total unavoidable losses	....	....
	Other Losses		
(91)	Heat loss due to incomplete combustion of carbon	....	....
(92)	Heat loss due to excess air entering furnace and moisture accompanying some T_4 to T_{10}	....	....
(93)	Heat loss due to theoretical dry gases, moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, T_{10} to T_7	....	....
(94)	Heat loss due to excess air entering furnace and moisture accompanying same, T_{10} to T_7	....	....
(95)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_7	....	....
(96)	Heat loss due to air and moisture leaking through economizer setting, T_1 to T_7	....	....
(97)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....
	Economizer		
(98)	Heat available to economizer in flue gases, including moisture, T_6 to T_{10}	....	....
(99)	Efficiency of economizer	....	....

TABLE 11*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, AND ECONOMIZER. GASEOUS FUELS

Item

(84) = *Item* 33

(85) = *Item* 78×970.4

(86) = $(H_1 - H) \times$ *Item* 77

(87) = $(h - h_1) \times$ *Item* 77

(88) = $(1090.7 + 0.455T_{10} - T_{12}) \times \left(\dfrac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100} \right) + (\textit{Item } 43 - C) \times \textit{Item } 45 \times 0.455 \times (T_{10} - T_4)$

(89) = $\textit{Item } 43 \times (T_{10} - T_4) \times 0.24$*

(90) = *Item* 88+*Item* 89

(91) = $\dfrac{CO}{CO_2 + CO} \times C \times 10160$. (Use data from Item 36.)

(92) = $(\textit{Item } 39 - \textit{Item } 43) \times (T_{10} - T_4) \times (0.24 + \textit{Item } 45 \times 0.455)$

(93) = $(T_7 - T_{10}) \times \left\{ \textit{Item } 43 \times 0.24 + \left[(\textit{Item } 43 - C) \times \textit{Item } 45 + \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100} \right] \times 0.455 \right\}$

(94) = $(\textit{Item } 39 - \textit{Item } 43) \times (T_7 - T_{10}) \times (0.24 + \textit{Item } 45 \times 0.455)$

(95) = $(\textit{Item } 40 - \textit{Item } 39) \times (T_7 - T_1) \times (0.24 + \textit{Item } 45 \times 0.455)$

(96) = $(\textit{Item } 41 - \textit{Item } 40) \times (T_7 - T_1) \times (0.24 + \textit{Item } 45 \times 0.455)$

(97) = *Item* 84 − Sum of *Items* 85, 87, to 96, inclusive.

(98) = $(T_6 - T_{10}) \times \left\{ \textit{Item } 40 \times 0.24 + \left[(\textit{Item } 40 - C) \times \textit{Item } 45 + \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100} \right] \times 0.455 \right\}$

(99) = $\dfrac{\textit{Item } 87}{\textit{Item } 98}$

* NOTE—*Items* 89, 92, 93, 94, 95, 96 and 98. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

NOTE—*Items* 88, 92, 93, 94, 95, 96 and 98. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 12*b* HEAT-BALANCE OF A STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, ECONOMIZER, AND AIR HEATER. GASEOUS FUELS

Item	Heat Values	B.t.u.	Per cent
(84)	Heat per lb. fuel as fired (high heating value)	....	....
(85)	Heat absorbed by water and steam in boiler and superheater	....	....
(86)	Heat absorbed by steam in superheater	....	....
(87)	Heat absorbed by water in economizer	....	....
	Losses		
(88)	Heat loss due to incomplete combustion of carbon	....	....
(89)	Heat loss due to theoretical dry gases, T_2 to T_8	....	....
(90)	Heat loss due to moisture in fuel, moisture accompanying theoretical air, and water from the combustion of hydrogen, up to T_8	....	....
(91)	Heat loss due to excess air entering furnace and moisture accompanying same, T_2 to T_8	....	....
(92)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_8	....	....
(93)	Heat loss due to air and moisture leakign through economizer setting, T_1 to T_8	....	....
(94)	Heat loss due to air and moisture leaking through air heater setting, T_1 to T_8	....	....
(95)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....
	Economizer		
(96)	Heat available to economizer in flue gases including moisture, T_6 to T_{10}	....	....

(Continued on page 565)

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Research Committee of Engineering Division of National Research Council

THE following research committees of the Division of Engineering of the National Research Council have been corrected to date as follows:

Advisory Board on Highway Research (W. K. HATT, *Director*), A. N. JOHNSON, *Chairman*
- Character and Use of Road Materials, H. S. MATTIMORE, *Chairman*
- Economic Theory of Highway Improvement, T. R. AGG, *Chairman*
- Tractive Resistance of Roads, C. J. TILDEN, *Chairman*
- Structural Design of Roads, A. T. GOLDBECK, *Chairman*
- Highway Traffic Analysis, G. E. HAMLIN, *Chairman*
- Highway Finances, J. D. MCKAY, *Chairman*

American Bureau of Welding (WM. SPRARAGEN, *Secretary*), C. A. ADAMS (*Director*)
- Electric Arc Welding, H. M. HOBART, *Chairman*
- Gas Welding, S. W. MILLER, *Chairman*
- Welding of Storage Tanks, J. C. LINCOLN, *Chairman*
- Pressure Vessels, H. L. WHITTEMORE, *Chairman*
- Welding Wire Specifications, C. A. MCCUNE, *Chairman*
- Training of Welding Operators, J. C. WRIGHT, *Chairman*
- Standard Tests for Welds, F. M. FARMER, *Chairman*
- Specifications for Steel to be Welded, W. J. BECK, *Chairman*
- Resistance Welding, H. LEMP, *Chairman*
- Thermit Welding, J. H. DEPPELER, *Chairman*
- Welded Rail Joints, G. K. BURGESS, *Chairman*

Electrical Core Losses, A. E. KENNELLY, *Chairman*
Electrical Insulation, JOHN B. WHITEHEAD, *Chairman*
Relation of Quality and Quantity of Illumination to Industry, D. C. JACKSON, *Chairman*
Fatigue Phenomena of Metals, H. F. MOORE, *Chairman*
Hardness Testing of Metals, A. E. BELLIS, *Chairman*
Heat Treatment of Carbon Steel, F. B. FOLEY, *Chairman*
Marine Piling Investigations (W. G. ATWOOD, *Director*), R. T. BETTS, *Chairman*
Molding Sands, R. A. BULL, *Chairman*
Neumann Bands, C. E. MUNROE, *Chairman*
Pulverizing, G. H. CLEVENGER, *Chairman*
Uses of Tellurium and Selenium, V. LENHER, *Chairman*

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Building Materials A3-23. DISINTEGRATION OF CEMENT IN SEA WATER. A paper on this subject was presented by Wm. G. Atwood and A. A. Johnson at the June 13th meeting of the American Society of Civil Engineers. This report is available as a preprint and will appear in the August Proceedings of the American Society of Civil Engineers. It includes a review of literature of cement disintegration and describes foreign experiments, and recommends others in connection with cement in sulphate-bearing waters. A résumé of the paper was presented before the annual symposium of the American Society for Testing Materials on Concrete during the latter part of June.

Chemistry, Industrial A1-23. EXPLOSIVES, THEIR MATERIALS, CONSTITUTION, AND ANALYSIS. See *Explosives and Explosions A2-23.*

Electricity, General A1-23. METHODS OF MEASURING THE PROPERTIES OF ELECTRICAL INSULATING MATERIALS. This paper gives a series of electrical, thermal, chemical, and mechanical test methods which have been found useful in the study of solid electrical insulating materials. The several tests described are those used in obtaining the data previously reported in Technologic Paper No. 216 of the Bureau of Standards entitled Properties of Electrical Insulating Materials of the Laminated Phenol-Methylene Type. The several test methods described are radio-frequency phase difference or power loss, dielectric constant and flash-over voltage, direct-current surface resistivity and volume resistivity, tensile modulus of strength, modulus of elasticity (tensile), proportional limit, modulus of rupture, elasticity (transverse), Brinell hardness, scleroscope hardness, resistance to impact, permanent distortion, density, moisture absorption, machining qualities, thermal expansivity, and the effects of heat, acid, and alkali.

Address Superintendent of Documents, Government Printing Office, Washington, D. C., requesting Bureau of Standards Scientific Paper No. 471. Price 15 cents.

Explosives and Explosions A2-23. EXPLOSIVES, THEIR MATERIALS, CONSTITUTION, AND ANALYSIS. This bulletin is intended to cover present methods employed in the industry and to include all classes of explosives and the materials used in their manufacture. Explosives are here grouped as dynamites, black powders, propellants, detonators, and primers. Some materials are used in practically all these groups; others in only one. To discuss all the materials that have been or that may be used and the methods for their identification and quantitative determination is not feasible, but the methods described will probably suggest ways of examining new mixtures.

This report known as Bulletin 219 of the Bureau of Mines was prepared by Messrs. C. A. Taylor and W. H. Rinkenbach and may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 20 cents.

Heating and Ventilation A1-23. RADIATOR TRAPS. For the past two years the Research Committee of the National Association of Building Owners and Managers has been making an exhaustive study of radiator traps now on the market. Its complete program calls for a report on the construction and functioning of these traps as determined by both laboratory tests and the careful record of experience in building operation.

Realizing the great need for reliable information on this subject the Committee has just published a preliminary report which covers only the first part of its program. This report includes a brief statement of thermodynamic theory; an outline of steam heating in general, with the relation of radiator traps thereto; a drawing and description of each of the principal makes of trap; and a detailed statement of the results of the laboratory tests of each such make.

For copies of the report, which covers 68 pages (8½ by 11 in.), address Mr. L. B. Ermeling, Executive Secretary of the National Association of Building Owners and Managers. Price $5.

Internal-Combustion Engines A1-23. GASOLINE SAVED ON TRUCKS BY ADJUSTING CARBURETORS BY EXHAUST-GAS ANALYSIS. These tests were made at the Government Fuel Yard, operated at Washington, D. C., by the Bureau of Mines, Department of the Interior, in order to determine and improve the adjustment of the carburetors on the trucks used for transporting coal from the Fuel Yard to the different Government buildings in Washington. The trucks used range in capacity from 2½ to 7½ tons and the majority of the carburetors were of standard type. At the time the tests were made about ten trucks were in daily use.

Samples of the exhaust gas were taken on the trucks kept in service for summer hauling in order to determine the carburetor adjustment as used. Changes were then made to a more economical adjustment wherever possible, without sacrificing flexibility of operation and power. In every case the adjustments were maintained for maximum power, but were adjusted to the leanest position to give that power. In all but one case the carburetors were found to be adjusted too rich for maximum power and economy. These results are considered in detail in the report.

The actual increase in mileage and saving of gasoline due to the carburetor adjustments made by gas analysis, when the months preceding and following the adjustments are compared, showed an increase in mileage of 22 per cent, and for the second month after adjustment, 16 per cent, and the third month 9 per cent. When the mileage is compared truck for truck, and not taking into consideration the distance each traveled during the month, the increased mileage equaled 24.7, 21.2 and 16.2 per cent, respectively.

The tests show that a portable CO_2 indicator for testing the exhaust gases of a motor vehicle, as used in these tests, gives a positive indication of the carburetor adjustment, removes all guesswork from such adjustment, is perfectly feasible practically, and almost indispensable to a company having ten or more large trucks in service, especially if supplied with adjustable carburetors.

Messrs. G. W. Jones and A. C. Fieldner are the authors of this report which is known as Serial 2487 and may be obtained by addressing H. Foster Bain, Director of the Bureau of Mines, Department of the Interior, Washington, D. C.

Marine Engineering A1-23. DISINTEGRATION OF CEMENT IN SEA WATER. See *Building Materials A3-23.*

Welding A1-23. WELDING OF OIL STORAGE TANKS. The design of a 5000-barrel tank by both the electric-arc and oxy-acetylene welding processes has been completed. A report of the electric-arc method, including specifications, was published in the December, 1922, issue of the American Welding Society. A report on the oxy-acetylene welding method has just been completed and was published in the June, 1923, issue of the Journal of the American Welding Society. The latter report includes photographs of two tanks constructed according to this method.

The general object of this investigation was to design a welded storage tank which will enable the reduction of loss of the lighter oils from leakage and evaporation now accruing in the present riveted construction.

Welding A2-23. Application of Arc Welding in Ship Construction. A comprehensive report has been prepared by E. H. Ewertz, general manager of the Moore Plant of Bethlehem Shipbuilding Company, under the guidance of the Electric Arc Welding Committee, and is now being published as a serial in *Marine Engineering*. The report includes cost figures, test data, relative advantages of welding versus riveting, service results of applications, and different designs of welded ships.

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Building Materials B3-23. Penetration Tests for the Workability of Concrete Mixtures. The laboratory work in connection with the development of a penetration test for the workability of concrete mixtures has recently been completed at the Bureau of Standards.

The outstanding results obtained from the penetration test in this investigation are: (*a*) the relative effects of celite, kaolin, hydrated lime, and other admixtures upon the workability of the concrete have been determined; (*b*) the workability of concrete mixture varies only moderately with change in consistency or flow and is more dependent upon the character and proportions of the solid ingredients than upon the quantity of mixing mortar; (*c*) the workability of concrete mixtures shows a maximum of medium-wet consistency; (*d*) the workability of concrete mixtures depends upon two factors, segregation and lubrication, either one of which may be controlled by suitable changes in the ingredients of the concrete.

Fluid Flow B3-23. Investigation of Orifice Gas Meters. For several months the Bureau of Standards has had under way the preliminary arrangements for an investigation of the performance of orifice meters. The investigation will be limited to a study of the orifice meter of the type used in the commercial measuring of gas, the principal problem being to determine the discharge coefficient under all the variable circumstances which may occur within the range of commercial or engineering practice.

Up to the present time only a few preliminary runs have been made. During these runs approximate checks were made of the discharge coefficients of the flow nozzles which are to be used in the final measurement. These runs have also served to bring out defects in the equipment and have thus furnished a basis for making alterations and improvements. It is expected that actual tests will be started within a short time.

Gases B3-23. Investigation of Orifice Gas Meters. See *Fluid Flow B3-23.*

Hardness B2-23. Steel for Brinell Balls. In measuring the hardness of metals by the Brinell method, a hardened steel ball is forced into the specimen by hydraulic pressure, the amount of penetration serving as an indication of the hardness of the sample. Difficulty has been found in measuring the Brinell hardness of steel having a hardness over 500 B.h.n. An attempt has been made by the Bureau of Standards for the past 3 or 4 years to obtain a very hard steel which will carry the load of 3000 kg. without fracture, but up to the present without success. Tungsten carbide has been suggested, but it has been impossible to obtain this material in suitable condition in either this country or Germany. Recently a very hard vanadium steel made at the Bureau's laboratories has been tried and shows promise of success. More of it will be made, and if future experiments are successful, an important advance in the art of hardness testing may result.

Steel, Its Treatment and Products B3-23. Quenching Effect of Oil-Water Emulsions on Gage Steel. Considerable time has recently been given at the Bureau of Standards to a study of the characteristic behavior of an oil-water emulsion (a mixture used commercially to some extent) as a quenching medium in the heat treatment of steels. It was found necessary to stir the mixture with high-pressure air to obtain a homogeneous emulsion in which condition it was very stiff and cooled the specimen much more slowly in the upper temperature range than oil. It had the peculiar property of cooling slowly halfway and then very rapidly, the time to cool to one-tenth of the temperature range being about the same as for oil. This unique property is evidently due to entrapped air and should be studied further.

D—Research Equipment

The purpose of this section of Engineering Research is to give in concise form notes regarding the equipment of laboratories for mutual information and for the purpose of informing the profession of the equipment in various laboratories so that persons desiring special investigations may know where such work may be done.

Iron and Steel D1-23. Additional Foundry Equipment. Up to the present time, nearly all the work of the Bureau of Standards' foundry has been limited to the preparation of non-ferrous alloys. Recently the Bureau has purchased a small cupola to be used for investigational metal for castings used by the Bureau and other branches of the Government. During the past month, the construction of a charging platform and foundations for the cupola were completed. The installation and lining of the cupola are now in progress and the equipment will soon be ready for service.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The First Steam Locomotive Run on Rails in America

To the Editor:

In your issue for June, I notice on page 391 that you give a picture entitled "The *Stourbridge Lion*, The First Steam Locomotive Run on Rails in America." In the article accompanying this illustration you state, "The *Stourbridge Lion* was the first locomotive placed on any track outside of England, and the first that ever turned a wheel on the Western Hemisphere." In justice to the pioneer engineering work done by John Stevens I feel that it is no more than right to correct the impressions given by the quotations I have just made from your article.

In the year 1826, John Stevens constructed at his own expense a locomotive with a multitubular boiler which he operated for several years on a circular track on his estate at Hoboken. This track was laid in the level ground south of Castle Point and almost immediately in front of the site now occupied by Stevens Institute of Technology. A model of this locomotive with the original multitubular boiler is now preserved in the National Museum at Washington.

Not only was it three years after this achievement of John Stevens that the *Stourbridge Lion* was operated in this country, but it is to be noted as of no little importance to the credit of Mr. Stevens that his locomotive was designed and built by him in America, whereas the *Stourbridge Lion* was imported from England. An extended reference as to the accomplishment of John Stevens in building and operating what was really the first locomotive in America driven by steam and upon tracks is to be found in the addresses of J. Elfreth Watkins, at one time curator of the Section of Transportation and Engineering of the United States National Museum, before the Philosophical Society of Washington, May 7, 1892, and at the dedication of the monument erected by the Pennsylvania Railroad at Bordentown, N. J., November 12, 1892.

Franklin DeR. Furman.

Hoboken, N. J.

Boiler-Furnace Design

To the Editor:

The writer had the pleasure of being present at the meeting of the Metropolitan Section of The American Society of Mechanical Enginers when Edwin Ricketts presented his interesting paper on Boiler-Furnace Design, subsequently published in Mechanical Engineering.[1] The following comments are made to discuss and interpret the facts in that part of the paper which deals with wall construction.

[1] Vol. 45, No. 5, May, 1923, pp. 299–304.

The importance of proper wall insulation and its effect in increasing boiler economy are clearly shown in Fig. 5 of Mr. Rickett's paper. The heat loss through the wall, which is composed of 9 in. of firebrick, $4^1/_2$ in. of insulating brick, and $8^1/_2$ in. of red brick with a furnace temperature of 2500 deg. fahr. is 310 B.t.u. per sq. ft. per hr. With the wall composed of $13^1/_2$ in. of firebrick and 9 in. of red brick, the heat loss with a furnace temperature of 2500 deg. fahr. is 776 B.t.u. per sq. ft. per hr. The saving due to insulation, therefore, is 776−310, or 466 B.t.u. per sq. ft. of boiler wall per hr. A computation will bring these savings down to dollars and cents.

For a boiler furnace 24 ft. wide, 20 ft. high, and 14 ft. long the total area through which heat radiates—side walls and front—equals 1040 sq. ft. Assuming further that the boiler in the case operates 300 days per year, 24 hours per day, on coal which has a heating value of 13,500 B.t.u. per lb. and is valued at $6 per ton of 2000 lb. on the grate, with a boiler efficiency of 75 per cent the saving in B.t.u. per year equals 3,489,408,000; the saving in tons of coal will be 178.94 per annum, and the saving in dollars will be $1073.64.

To insulate one square foot of surface $4^1/_2$ in. thick, 6.5 insulating brick would be required. The best insulating brick are $9 \times 4^1/_2 \times 2^1/_2$ in., standard firebrick size. A certain number of red brick

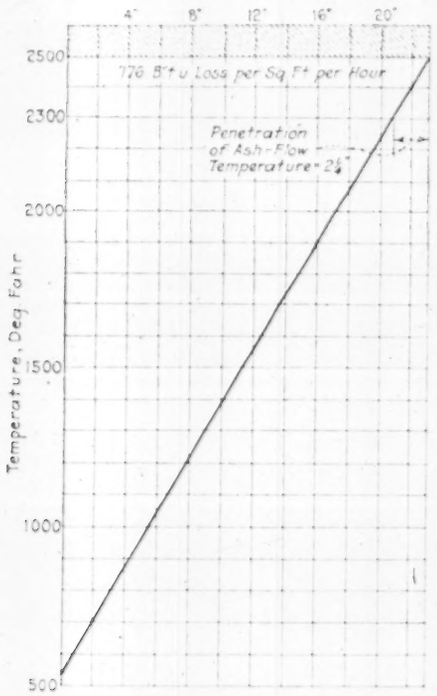


FIG. 1 TEMPERATURE GRADIENT THROUGH WALL COMPOSED OF FIREBRICK AND RED BRICK

will be displaced by the insulating brick—the red brick are usually about $8 \times 4 \times 2$ in.—and 8.5 brick will be displaced per square foot by the use of insulation.

Figuring the cost of insulating brick for the above area of 1040 sq. ft. at $100 per M on the ground, the gross investment in insulation is 6750 ÷ 1000 × $100 or $675. The value of the same number of red brick displaced, together with the value of the additional red brick displaced and the labor required to lay the additional red brick, is as follows:

6750 red brick at $20 per M with mortar	=	$135.00
2100 red brick at $45 per M with mortar and labor	=	94.50
		$229.50

Deducting this amount from the gross investment leaves a net investment in insulation of $445.50. The return of the net investment in insulation is therefore ($1073.64 ÷ $445.50) × 100 = 241 per cent. Thus insulation of a boiler furnace is justified from a fuel-conservation standpoint alone.

Fig. 1 shows the temperature gradient through a wall composed of $13^1/_2$ in. of firebrick and 9 in. of red brick. The temperature gradient for firebrick and red brick is not in reality a straight line, but it may be considered so when used in connection with this discussion. The penetration of ash-flow temperatures is shown to be about $2^1/_4$ in.

Fig. 2 shows another wall composed of 9 in. of firebrick, $4^1/_2$ in. of insulating brick, and $8^1/_2$ in. of red brick. The temperature gradient through the insulated wall is shown in solid line. The dotted line is that for the temperature gradient through firebrick and red brick, from Fig. 1, which has been superimposed to facilitate comparison of temperature gradients. This shows plainly that there is an increase in temperature on the back of the firebrick of only 150 deg. fahr. due to insulation. The penetration of ash-

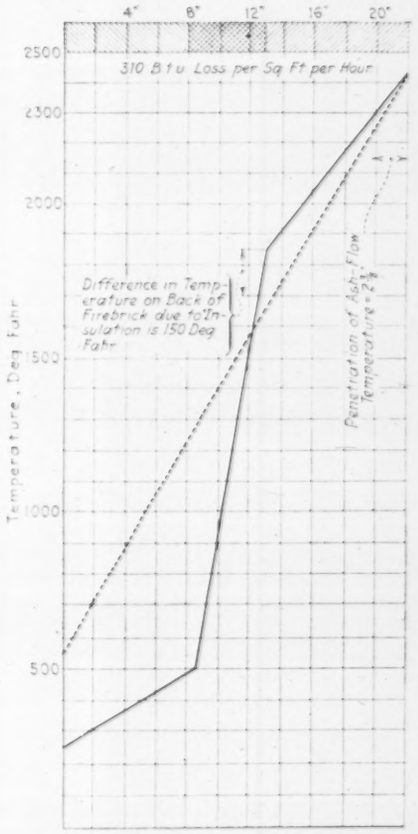


FIG. 2 TEMPERATURE GRADIENT THROUGH WALL COMPOSED OF FIREBRICK, RED BRICK, AND INSULATING BRICK

flow temperatures in the insulated walls is about $2^3/_8$ in. This is practically the same as that shown for the solid firebrick and red-brick construction.

But in actual practice the insulated wall, in spite of higher temperature at the back of the firebrick, would probably have a longer life of refractory lining because, with a given boiler producing a given amount of steam, the temperature in the insulated furnace will be less than the temperature in the uninsulated furnace.

Insulating brick can be easily installed between the firebrick and the red brick in brick-set boilers, or between the firebrick and steel casing in steel-encased boilers. The proper thickness of refractory lining should always be allowed as a protection for the insulating brick. With the insulated-wall construction and capacities as previously mentioned, it would be highly desirable to use an insulating brick which would withstand a temperature of 2000 to 2100 deg. fahr. without change in character or size.

Mr. Ricketts brings out the difficulties encountered when fireclay is used to lay up refractory lining in boilers operating at high capacities. But a good grade of high-temperature cement forms a definite bond between the firebrick and, if used, eliminates any danger of cracks which would allow the molten ash to get into the brickwork.

Based on this information the logical conclusion is that the ideal boiler wall is an insulated one, whether the boiler be brick-set or steel-encased.

C. A. FRANKENHOFF.

East Orange, N. J.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

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Warren Gamaliel Harding

By the untimely death of President Harding, the country has lost a kindly man who brought to the solution of many troublesome problems that lay in the wake of the war, the neighborly impulse for conciliation which will long keep his memory warm.

His Foreword to the F.A.E.S. Report on the Twelve-Hour Shift in American Industry and the pledge he drew from the iron and steel industry for the speedy elimination of the long-shift day are indelible evidences of the humanitarian principles which will mark him as one to whom posterity will be grateful.

The sorrow of the nation over the death of President Harding is profound and sincere. It is an expression of love and respect, and a recognition of great loss.

The Twelve-Hour Day

THE DEFINITE STEP taken by the United States Steel Corporation to abolish the twelve-hour day in continuous-process work is an outstanding recognition of the principle, supported by the late President Harding and general public opinion, that a "twelve-hour shift day is too long when measured by twentieth century ideas as to the proper conduct of industry." This action in the steel industry is of increased importance in that it points the way to the reduction of twelve-hour work in many other industries. The report issued last fall by the F.A.E.S. Committee on Continuous-Work Periods lists some forty industries in which 300,000 wage earners are on twelve-hour shifts. The long-shift workers in the steel industry number 150,000. Popular imagination has been excited by graphic pictures of heavy toil before fiery steel furnaces but the arduous twelve-hour periods in other continuous-process work is equally in opposition to modern ideas.

The change from the long day is a serious matter. No sudden, poorly conceived plan can bring permanent good to any industry and such a scheme may retard the consumation of desired results. Though hasty action in such an important matter should be avoided, immediate consideration of ways and means is important, so that at the proper moment a well-thought scheme may be put in use. The F.A.E.S. Report, referred to above should impress industrial engineers and executives with the immediate necessity for a study of the subject. It indeed contains many examples of the successful abolition of the twelve-hour day, sometimes with increase in economy and generally with an increase in the well-being of the workers and the industry.

The degree of success of the change from the twelve-hour day depends upon a great number of variables, differing in different industries and plants, but the critical conditions of a practical plan are "the readiness of the men to do more work in the shorter shift" and the acceptance of the management of responsibility of a high order to plan, supervise, and control so that the productive capacity of the men shall be steadily maintained during the shorter period. Much could be said on this point. Its importance is fundamental and there is evidence that the change to the three-shift basis stimulates improvements in management functions and in methods and equipment which go far toward balancing or may even overbalance, the increased labor cost anticipated by those who compute it upon a simple arithmetic basis.

Dean Kimball regards the abolition of the twelve-hour day as the acceptance of an industrial ideal which marks a distinct advance in economic progress. His views, given herewith, are of considerable interest.

"To students of industrial history the abolition of the twelve-hour day would seem to be a foregone conclusion. It is a relic of the dark ages of industry that are rapidly disappearing before a more enlightened understanding of the larger purposes of industry, and particularly of modern methods of production. These purposes in their essence are that men shall live more like human beings and less like animals. Otherwise, there is no worth-while achievement in labor-saving methods, labor-saving machinery and other means of increased production.

"The argument that such changes are not economically possible is the foremost argument that has been advanced against all such changes since the days of the Industrial Revolution. The entire history of modern industry shows that this argument is falacious. If any group of employers and employees have a real desire to shorten the length of their working period it can be done. Capital may have to be content temporarily with smaller profits, and labor may have to work more industriously, at least for the time being, but if those who are interested in such a movement in any industry see to it that no stone is left unturned within the industry itself that will aid in accomplishing this end, the public will gladly pay the difference in cost occasioned by a reasonable shortening of working hours.

As the editorial in this issue points out, any change of this kind in a large industry is a serious matter, not to be gone into precipitately, but if approached in an intelligent manner the change can surely be brought about. Without doubt the twelve-hour shift will disappear from American industry in a not far distant future."

A. P. Davis' Dismissal a Blow to Sound Government

"THE summary dismissal of Arthur Powell Davis from the directorship of the United States Reclamation Service is a vital blow to the cause of sound government and therefore a matter of grave concern to every responsible citizen. It demonstrates that even one of our highest national executives does not hesitate to evade Civil Service Law by a subterfuge, to terminate a lifetime of faithful, competent service for personal or political reasons and so to deter competent men from serving the nation, nor to accuse the entire engineering profession of business incompetence in the face of overwhelming evidence to the contrary even in the case in point.

It is imperative that all who demand honorable conduct of the nation's affairs, and particularly that all engineers shall vigorously resent the action of the Secretary of the Interior, and the motives he is reported to have given for it."

The foregoing statement by John Lyle Harrington, President of The American Society of Mechanical Engineers, is but one of a number of forceful protests against Mr. Davis' removal.

The Secretary of the Interior explained his action as a "simple incident of reorganization and the putting of a business man in

charge." Although having served the Government faithfully and well for over forty years Mr. Davis was denied a hearing to which he was entitled under Civil Service regulations on the grounds that the office of Director had been abolished. A former governor of Idaho, D. W. Davis, took over the work under the title of "Commissioner of Reclamation."

At its meeting in Chicago, July 10, the Board of Directors of the American Society of Civil Engineers issued a statement in protest of Secretary Work's action as follows:

The Reclamation Service has had an honorable and a creditable career of over twenty years. Its conduct during that period has been under the constant surveillance of the officers of the National Administration, of members of Congress and of the residents of the numerous committees in which the projects have been constructed.

The nature of its operations is such as to arouse the watchful care of those who are to be served and the active opposition of those whose interests might run counter.

Throughout this long period there has been no scandal and no sustained charge of lack of faithful loyalty to public interests. The works erected and the precedents established serve as worthy examples for our own country and have been used as a guide in such developments in other lands. The personnel of the Service has been remarkably loyal, conscientious and devoted to a high standard of public service. The dismissed Director has been either chief engineer or Director since the establishment of the work in 1902, and was at least entitled to a written statement of reasons for dismissal as provided in Civil Service regulations, and as required in proper administrative practice.

The reported reason of better administration advanced for the replacement of the Director by a successor under the new title of Commissioner, appears to be a pretext which is refuted by the long and honorable business record of the Director dismissed, in comparison with such record as we can obtain of the appointee selected to succeed him. The implication that engineers are not competent business administrators is refuted by numerous engineers who today are conducting as executives, many of the great railroad systems, public utilities and industrial enterprises of this and other countries, and the U. S. Reclamation Service is peculiarly an engineering enterprise.

The Board fears that any pretext of better administration could only be regarded as a perversion of the proper precepts of a rightful economy to suit the needs of an ever present political situation.

The Board deplores the action taken by the Secretary of the Interior, for the following reasons:

1 That it will work irreparable injury to the public service in the breakdown of morale and confidence of public employees

2 That it is an injustice to a man who has given forty-one years of faithful and valuable service to the Government of the United States

3 That arbitrary methods of removal are not creditable to a popular government based upon equality and fair dealing

4 That the change now inaugurated bears evidence of an attack upon a worthy and highly creditable branch of the government service to serve political needs

5 That the conversion of the Reclamation Service into a political machine would result in the withdrawal of public confidence and national financial support with the resultant injurious effect upon the development of the West.

The serious feature of Mr. Davis' dismissal is its discouraging effect on the large number of extremely capable engineers who are in the service of our Government. John R. Freeman, Past President of both The American Society of Mechanical Engineers and the American Society of Civil Engineers, in a letter addressed to Mr. Davis stated that "nothing recently has so shocked me as tending to the destruction of public service of high quality as the announcement of your dismissal after forty years of faithful service and a record of admirable efficiency." L. W. Wallace, Secretary of the American Engineering Council, wrote that "this incident will undermine the morale of all the technical agencies of the Government and may lead the most competent men to accept more readily engagements with commercial agencies, thus interfering with the efficient operation of the technical bureaus of the Government."

The Engineering News-Record emphasized the seriousness of the Davis incident and stated "that it may well be the beginning of a movement at Washington to make the government engineers merely the day-laborers of engineering work, the bosses of the concrete gangs, the instrument men of the surveys, the draftsmen and the estimators, leaving the direction of all of these to the so-called business man, who changes with each new administration or even with the political exigencies of the administration itself."

F. R. Low summed up the situation in a strong editorial in *Power*, an abstract of which follows:

"The hoped-for recognition of the importance of the engineer in governmental functions got a setback, when Arthur P. Davis was asked by Secretary Work of the Department of the Interior to hand in his resignation as Director of the Reclamation Service.

"Why was he put out?

"The reason given by the Secretary is that he wants to put a business man in charge. So he appoints a man who was a successful grocer, not so successful a banker, but a clever politician.

"And so we have the spectacle of one highly professional man—not a business man himself, by the way—a past president of the American Medical Society, dismissing another highly professional man, a past president of the American Society of Civil Engineers, to make room for a business man as "Commissioner" of a service that is largely one of civil engineering.

"If this kind of a thing is allowed to stand unchallenged, all the talk of putting the engineer to the front in the reconditioning of the country is as sounding brass and a tinkling cymbal."

The engineering profession and the public are entitled to the facts and aggressive steps should be taken promptly to reveal all of the details incidental to the dismissal of Mr. Davis. The ideals and functions of the engineering profession have been challenged.

Definition of Net Generator Output

THE Electrical Apparatus Committee of the American Institute of Electrical Engineers has outlined a set of definitions to be applied in determining the output of electric generators. These definitions have been divided into two principal parts, the first part covering measurements for station logging purposes where great accuracy is not necessary, while the second part covers test conditions where greater refinement is necessary.

This matter has been submitted to The American Society of Mechanical Engineers for comment.

The definitions as they now stand are given below, so that the membership will have an opportunity of criticising them. Any member having comments to offer will please address their communication to Herbert B. Reynolds, Secretary Power Division, 600 West 59th Street, New York City.

"For the purposes of station logging the generator output shall be considered to be the kilowatt-hours generated in a given period by the main unit.

"For purposes of efficiency determinations of the generators themselves or for purposes of comparison with other units this definition shall be modified in accordance with the following paragraphs:

1 In the case of a separately driven exciter, minus the power consumed in generator field and field rheostat.

2 In the case of a separately driven ventilating fan, minus the power input to the fan.

3 In the case of a direct-connected exciter, plus the kilowatt-hours generated by the exciter minus the power consumed in generator field and field rheostat.

4 In the case of a direct-connected auxiliary unit for supplying excitation and for power for turbine auxiliaries, plus the kilowatt-hours generated by the auxiliary unit, minus the power consumed in generator and auxiliary unit fields and field rheostats."

H. B. REYNOLDS,
Secretary Power Division A.S.M.E.

Errata

On page 473 of the August issue of MECHANICAL ENGINEERING, in the paragraph on The Salt-Velocity Method of Measuring Flow (a part of the paper on Modern Hydraulic Turbines of Large Capacity, by H. G. Acres), the following words should have been omitted: "and uniform section" in the fifth line of the paragraph, "of uniform section" in the ninth and tenth lines, and "an instantaneous" in the fourteenth line.

On page 426 of the July issue of MECHANICAL ENGINEERING in Mr. Toltz's discussion of Mr. Hood's paper on Lignite Char, reference is made to "lignite of 5400 B.t.u." This should read "lignite of 12,060 B.t.u.". The lignite in question was mined at the Mine Ernst of the Anhalt Coal Co. in middle Germany and is called "raw brown coal."

Formulas for Computing Economies of Labor-Saving Equipment

Committee of A.S.M.E. Materials Handling Division Studies Problem of Evaluating Labor Saved by Improved Processes—Practical Application of the Formulas Devised

THE COMMITTEE appointed by the Executive Committee of the A.S.M.E. Materials Handling Division to consider and recommend rational formulas for computing the economic results, under stated conditions, of the installation of labor—conserving industrial equipment, has submitted the following report for consideration.

The problem presented is one of comparative costs. The tendencies in current practice which it is desired to correct are simply lack of consistency in treating the debit and credit items involved. Incidental items, such as interest on investment, taxes, maintenance, depreciation, obsolescence, etc., in other words, "fixed charges" or "burden," are currently accounted on the debit side when calculating the costs of substituting mechanical processes for manual ones. It seems, however, to have been unusual to make any contingent addition in calculating the monetary value of labor saved by improved methods.

In principle the desired formula represents simply a mathematical expression of such debit and credit items as are involved in the proposed new method, or process, as compared with previous practice. In highly organized and thoroughly systematized industrial practice, however, direct expenditures and direct economies are frequently of less importance in their monetary value than related incidental expenditures and economies. For instance, labor is employed in the factory for processing a raw material, which is thereby enhanced in value and becomes the factory's product. As a rule the total cost of the process will consist of, say, one part "direct labor" (labor which can be charged directly to a single process, or part of the product) and from one-half to three parts "fixed charge," "burden," or operating charge, consisting of "indirect labor" (labor which is of general utility and not chargeable directly), and such items as superintendence, employees' liability, welfare activities, maintenance of buildings and machinery, fuel, supplies, insurance, depreciation, taxes, accounting, etc.

The real problem in composing a formula, therefore, is not one of mathematics, but of economics. Not only should there be added to each dollar expended for improved equipment a suitable incidental amount (in percentage of the capital invested) to cover fixed charges or burden, but also a suitable incidental addition (in percentage) should be made to each dollar's worth of labor saved, as its proportion of "burden" saved. The extent of the expenditure for items accounted as burden will usually bear some fairly proportional relation to the amount of labor performed.

When calculating the cost of the finished product, if an improved process or equipment affects the amount and hence the cost of the "direct labor," then, for the most accurate results, the burden should be applied to labor *saved* at the same rate as labor *used*.

For the purpose of ascertaining the cost of the product, non-productive labor, as a part of burden, should not be considered as subject to any contingent addition for burden. Yet for certain classes of accounting, particularly where comparative economies are being considered, non-productive labor may carry all items of burden that are chargeable to direct labor, except that it carries no contingent addition for its own class of indirect labor. It entails superintendence, employees' liability, welfare work, penalties for overtime and holidays, capital for payrolls, housing, heating and lighting, with the incidental maintenance, taxes, depreciation, and other charges, in the same way as direct labor.

Since a new process must of necessity be considered in comparison with an established process, no "burden" need be considered in respect to the labor used in either case, because the burden charge per unit of labor in one process will offset an equal unit of labor in the other process. The difference in labor required, however, must, in the interest of accuracy, be subject to its appropriate addition for "burden." For this class of cost accounting the cost department of an industry should ascertain the proper percentage to add for burden on both "productive" and "non-productive" labor.

Handling materials is practically always an important item of cost in manufacturing. With a complex product it would be difficult to charge handling costs to individual materials; and it is usually accounted as "non-productive" labor and distributed to various items of product, through an addition in the way of a percentage on direct labor, or an equivalent method, in common with other items of "burden." Here we have an example of labor expended in handling miscellaneous materials which would be accounted as "non-productive" labor.

If, however, we consider the employment of labor in transportation, in the handling of miscellaneous materials, it would naturally be accounted as "direct" labor, since it accomplishes an important and definite step in the process of transportation, and should therefore be subject to its pro rata share of all fixed charges whether it is labor used or labor saved by an improved process or by the substitution of mechanical process.

In the opinion of the committee, current practice which usually takes no account of "fixed charges" or "burden" on the excess of labor used by one process or on the labor saved by another process, represents a grave error in any analysis of comparative costs. Also in some cases where "burden" is added to "direct labor" in calculating comparative costs, it is omitted entirely where the labor is accounted as "non-productive," or indirect.

Based upon these considerations the following rule for setting a value upon labor saved by an improved process has been evolved:

> Whatever valuation is arrived at in cost accounting as the cost per unit of *labor used* in production, also establishes the value per unit of labor *saved* by an improved process. For simplicity, no monetary value need be placed upon labor employed in comparative processes, except upon the amount of *difference* in labor required at the current rate paid, plus "burden" or an equivalent.

Other items of cost should in like manner be accounted at the same rate as for similar items in making up the cost of product.

In calculating comparative cost a new item is introduced which never becomes a factor in regular cost accounting, namely, the monetary value of increased production. The profitableness of any industry stands or falls upon the relation between total cost of production and total volume, and hence value, of product.

An increase of product with a given equipment will affect the spread between cost and the market value of product just as vitally as an equivalent reduction in some or all of the items of cost. Accordingly, no system of comparative cost accounting can pretend to even approximate accuracy which does not place a suitable valuation upon increased productivity.

In placing a valuation upon increased productivity it should be borne in mind that in any industry the volume of product required to just meet the costs of the plant and a given organization affords *no profit;* also that any product above that amount is obtained without any manufacturing cost whatever; hence the rule:

> In a comparative accounting increased production will always carry a higher value than that attached to normal production.

The Committee therefore unanimously recommends the following methods:

Let:

Debit Items

- A = percentage allowance on investment
- B = percentage allowance to provide for insurance, taxes, etc.
- C = percentage allowance to provide for upkeep
- D = percentage allowance to provide for depreciation and obsolescence
- E = yearly cost of power, supplies, and other items which are consumed, total in dollars

Credit Items

- S = yearly saving in direct cost of labor in dollars
- T = yearly saving in fixed charges, operating charges or burden, in dollars
- U = yearly saving or earning through increased production, in dollars

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

X = percentage of year during which equipment will be employed
I = initial cost of mechanical equipment
Z = maximum investment in dollars justified by the above consideration,
Results Y = yearly cost to maintain mechanical equipment ready for operation
V = yearly profit from operation of mechanical equipment.

Then

$$Z = \frac{(S + T + U - E)X}{A + B + C + D} \quad [1]$$

$$Y = I(A + B + C + D) \quad [2]$$

and

$$V = [(S + T + U - E)X] - Y \quad [3]$$

Feeling that handling machinery, even if left idle a large part of the year, would probably require, under most conditions, approximately the same repair through deterioration as though in use, the Committee makes no deduction for such lack of use in the estimated cost of upkeep C. If greater accuracy be considered necessary, use C multiplied by X in place of C in the formulas.

Applications of the Formulas

As an example of an application of the formulas, assume that the handling of miscellaneous materials about a factory which has formerly been done by four men receiving $3.50 per day each, or, allowing 300 days per year, at an annual direct cost of $4200, can be done by one man operating an electric storage-battery industrial truck at a direct-labor cost of $1050 per year, thus effecting a saving at the rate of $3150 per year in direct-labor cost.

Assume also that through the greater promptness in moving materials and the more continuous operation of machines there is an increase in earnings, due to increased production, valued at $650 per year; also that the labor involved, being accounted as "non-productive," carries a fixed charge or burden of 10 per cent. In actual practice the plant operates 240 days per year or 80 per cent of the time. The various factors therefore, are estimated as follows:

A = 6 per cent — S = $3150
B = 4 per cent — T = 315
C = 20 per cent — U = 650
D = 25 per cent — X = 80 per cent
E = $450

$$Z = \frac{(\$3150 + \$315 + \$650 - \$450) \times 80}{55} = \$5331.$$

This indicates that equipment costing any sum below $5331 will earn some profit above interest on investment and maintenance.

Assume that an electric storage-battery industrial truck will meet the conditions stated and that its cost will be $2200. Then the yearly cost to maintain equipment ready for operation, exclusive of labor, will be expressed by the formula, $Y = I(A + B + C + D)$ or $2200 × 55 per cent = $1210. Then the profit from operation of the mechanical equipment, according to [3], becomes ($3150 + $315 + $650 — $450) × 0.80 — $1210 = $1722.

The profit V, or $1722, represents an annual earning upon the initial investment, over all items of cost, of over 78 per cent.

If, however, our example be applied to handling cargo at a railroad or marine terminal where the labor is *productive labor* and subject to *all* fixed charges as burden, an important difference in result will be had, indicating the importance of the factors T and U, and the necessity of placing proper values upon them if reliable results are to be had.

As such an example of an application of the formulas, assume that in handling miscellaneous cargo at a marine terminal, work which has formerly been done by four men receiving $3.50 per day each, or, allowing 300 days per year, at an annual direct cost of $4200, can be done by one man operating an electric storage-battery industrial truck at a direct-labor cost of $1050 per year, thus effecting a saving of $3150 per year in direct-labor cost.

Since this labor is productive labor, it will bear its pro rata share of all fixed charges, estimated at 50 per cent and to be added to the direct-labor cost, representing a further saving of $1575 on account of labor. Also that, through the greater promptness in unloading and loading vessels, 5 per cent more ships can be accommodated, accounting for 15 days' extra use of the pier yearly. Assuming the investment in the pier to be $1,000,000 and interest, taxes, etc., at 10 per cent, we have a credit item of 0.5 per cent to be divided, say, between 20 electric trucks, or $250 per truck per annum.

Applying the formulas as in the previous example, we have

$$Z = \frac{(\$3150 + \$1575 + \$250 - \$450) \times 80}{55}$$

= $6582 permissible investment.

The yearly cost of operation is $Y = \$2200 \times 0.55 = \$1210$ as in the previous example. The profit above maintenance charges, V, will then be ($3150 + $1575 + $250 — $450) × 0.80 — $1210 = $2410.

The profit $2410 represents an annual earning of nearly 110 per cent upon the investment in this case in place of 78 per cent in the previous example, all factors having been upon exactly the same basis except T (yearly saving in fixed charges) and U (yearly saving through increased production).

The following summary shows the relative value of the same device applied to two conditions, first, where the labor employed in the work is unproductive as regards producing an article of manufacture, and, second, where the labor used produces the salable commodity, in this case material handling.

	Case 1 Handling in Factory	Case 2 Handling in Marine Terminal
Cost of equipment	$2200	$2200
Z, investment justified	5331	6582
Y, yearly maintenance	1210	1210
V, profit from installation	1722	2410
Per cent return on investment	78	110

A study of this comparison indicates that with suitable values given to the factors the formulas proposed show not only the advantages obtainable under various conditions, but also that a device may be much more valuable per dollar invested in one industry than in another. The difference shown would have been much more pronounced had regular stevedores' wages been used for the wages of the man at the marine terminal.

The personnel of the committee which prepared this report consisted of W. F. Hunt, consulting engineer, New York, J. A. Shepard, of the Shepard Electric Crane & Hoist Co., Montour Falls, N. Y., and C. H. Newman, New York.

Stationary Steam-Generating Units

(Continued from page 558)

		B.t.u.	Per cent
(97)	Efficiency of economizer	....	....
	Air Heater		
(98)	Heat available to air heater in flue gases including moisture, T_2 to T_2	....	....
(99)	Heat absorbed by air heater	....	....
(100)	Efficiency of air heater	....	....

Note—If unit does not include economizer do not fill out Items 87, 93, 96 and 97. If data are available for further segregation of losses, other items may be added.

Table 12*d* Heat-Balance Computations for Steam-Generating Unit Comprising Boiler, Superheater, Economizer, and Air Heater. Gaseous Fuels

Item

(84) = *Item* 33

(85) = *Item* 78 × 970.4

(86) = $(H_1 - H) \times$ *Item* 77

(87) = $(h - h_1) \times$ *Item* 77

(88) = $\frac{CO}{CO_2 + CO} \times C \times 10160$

(89) = *Item* 43 × $(T_8 - T_2)$ × 0.24*

(90) = $(1090.7 + 0.455\ T_8 - T_{12}) \times \left(\frac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right) +$ (*Item* 43 − C) × *Item* 45 × 0.455 × $(T_8 - T_2)$

(91) = (*Item* 39 − *Item* 43) × $(T_8 - T_2)$ × (0.24 + *Item* 45 × 0.455)

(92) = (*Item* 40 − *Item* 39) × $(T_8 - T_1)$ × (0.24 + *Item* 45 × 0.455)

(93) = (*Item* 41 − *Item* 40) × $(T_8 - T_1)$ × (0.24 + *Item* 45 × 0.455)

(94) = (*Item* 42 − *Item* 41) × $(T_8 - T_1)$ × (0.24 + *Item* 45 × 0.455)

(95) = *Item* 84 − Sum of *Items* 85, 87 to 94, inclusive, and *Item* 99

(96*) = $(T_6 - T_{10}) \times \left\{\textit{Item } 40 \times 0.24 + \left[(\textit{Item } 40 - C) \times \textit{Item } 45 + \frac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right] \times 0.455\right\}$

(97) = $\frac{\textit{Item } 87}{\textit{Item } 96}$

(98) = $(T_7 - T_2) \times \left\{\textit{Item } 41 \times 0.24 + \left[(\textit{Item } 41 - C) \times \textit{Item } 45 + \frac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right] \times 0.455\right\}$

(99) = $(T_3 - T_2) \times$ *Item* 44 × (0.24 + *Item* 45 × 0.455)

(100) = $\frac{\textit{Item } 99}{\textit{Item } 98}$

* Note—*Items* 89, 91, 92, 93, 94, 95, 96 and 98. 0.24 is the value in common use for the specific heat of dry gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

Note—*Items* 90, 91, 92, 93, 94, 95, 96, 98 and 99. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Engineering and Industrial Standardization

Recent Progress in Standardization of Particular Interest to Mechanical Engineers

A.E.S.C. Considers Specifications for Cast-Iron Pipes. The American Gas Association has submitted for the approval of the American Engineering Standards Committee three specifications for cast-iron pipe and special castings.

These specifications were developed by the American Gas Institute in 1911, at which time the dimensions for bell-and-spigot castings were adopted. In 1913 the Association adopted the dimensions for flanged castings, and specifications governing the manufacture of all cast-iron pipe and specials, which were derived from an old standard adopted in 1905 by the American Gas Light Association. These again were based on seven years experience with the standards designed by the Society of Gas Lighting in 1890. It is said that the specifications now under consideration are in general use for underground gas pipes throughout the U. S.

The A.E.S.C. has appointed a large and thoroughly representative special committee to consider the application for the approval of these specifications, and sponsorship for future revisions under the regular procedure involving the organization of a representative sectional committee to consider and develop any changes required. S. G. Flagg, Jr., one of the representatives of The American Society of Mechanical Engineers on A.E.S.C., is chairman of this committee. He will be glad to receive at his address, S. G. Flagg and Company, 1421 Chestnut Street, Philadelphia, Pa., suggestions relative to the approval of the A.G.A. Standards and to the standardization of cast-iron pipe and fittings in general.

Overhead-Line-Material Specifications. The American Electric Railway Association has submitted its specifications for overhead-line material for action by the A.E.S.C., to determine the question of sponsorship and to arrange for the submission of the specifications already developed by the A.E.R.A. to a duly organized sectional or working committee, which will make such revisions and additions as may be necessary to bring these specifications up to the full status of an "American Standard." The special committee to consider the question of sponsorship and scope of the specifications, which are also of direct interest to other than electric-railway interests, is headed by A. H. Moore, representing the Electrical Manufacturers' Council on the A.E.S.C., and includes representation from the National Electric Light Association, American Railway Association, Electrical Manufacturers' Council, American Institute of Electrical Engineers, American Electric Railway Association, American Short Line Railway Association, and the Bell Telephone System.

The attitude of the A.E.R.A. in submitting its specifications for this action by the A.E.S.C. will very definitely favor the unification and elimination of conflicting specifications in this field, which is a very important one to a large group of industries and involves expenditures of great magnitude annually in construction, maintenance and replacement of power, light, telephone, telegraph, and railway signal lines.

Test Methods for Materials for Concrete Approved. The following A.S.T.M. methods of testing materials entering into concrete have been approved as "Tentative American Standards" by the American Engineering Standards Committee:

Method of Test for Unit Weight of Aggregate for Concrete
Method of Test for Voids in Fine Aggregate for Concrete
Method of Test for Organic Impurities in Sands for Concrete

The method of determining the impurities in sands had its origin in an investigation, begun in 1916, of a variety of concrete mixtures with different sizes and gradings of granite. The test, as a method, has proved itself useful for prospecting for sand supplies, preliminary examination of sands in the laboratory, and checking the cleanness of sands on the job.

The method for determining unit weight is the result of a very considerable amount of coöperative investigational work in which seven laboratories participated. The investigation shows that the particular method adopted gave more reproducible results than other methods; it was found in practice to be simple and commercially satisfactory and to furnish an easy basis for the computation of the percentage of voids.

In approving these standards the A.E.S.C. acted upon the recommendation of a special committee containing representatives of twelve interested organizations and under the chairmanship of Mr. T. H. McDonald, Chief of the Bureau of Public Roads.

The American Society for Testing Materials will act as sponsor for future revisions of these test methods.

Railway-Bridge Specifications. Specifications of interest to the railway and structural-engineering fields have recently been submitted by the American Railway Engineering Association for approval by the American Engineering Standards Committee as American Standards. They are as follows:

General Specifications for Steel Railway Bridges for Fixed Spans Less Than 300 Feet in Length, 1920, revised to May, 1923.

Specifications for Movable Railway Bridges, 1922.

A large special committee will be appointed by the A.E.S.C. to determine whether these specifications are suitable for adoption as national standards in this country. All the principal organizations interested in these two subjects will be invited to appoint representatives on this special committee.

In submitting the specifications the A.R.E.A. states that "the General Specifications for Steel Railway Bridges and the Specifications for Movable Railway Bridges were prepared by Committee XV on Iron and Steel Structures, of the American Railway Engineering Association. This is a standing committee and it has prepared all specifications for steel bridges adopted by the Association."

The A.E.S.C. would be very glad to learn from those interested of the extent to which these specifications are considered to meet the requirements of bridge-building practice and railway service.

Dictionary of Specifications. For the purpose of bringing about the general use of specifications as the basis for the purchase of supplies by the federal, state and municipal governments and public institutions, plans are now being inaugurated by the Department of Commerce for collecting into one dictionary or encyclopedia such specifications as have proved most satisfactory for this purpose.

In this dictionary will be included not only the specifications formulated under the Rules of Procedure of the American Engineering Standards Committee and those developed by the Federal Specifications Board, but all other specifications known to be satisfactory for the purchase of commodities not as yet covered by the specifications of the Board.

In selecting specifications for inclusion in the dictionary due consideration will be given to the attitude of the producers and consumers of the commodities toward them. In addition, federal, state and municipal governments and public institutions will be consulted. A comparison will be made between Government specifications and specifications for the same commodities formulated by well-established organizations of producers and consumers.

Dr. A. S. McAllister, engineer physicist, Bureau of Standards, who during the past two years has been liaison officer of the U. S. Bureau of Standards and the Federal Specifications Board, assigned to the headquarters of the American Engineering Standards Committee at New York, has been recalled to Washington by Secretary Hoover for this special work. He will welcome suggestions and data which will assist him in making the first edition of this volume as complete as possible.

Standardization of Railroad Ties. The personnel of the Sectional Committee for the Standardization of Railroad Ties is now announced by the American Engineering Standards Committee. Mr. John Foley, connected with the Pennsylvania System at Philadelphia and the representative of the American Railway Electric Association on the Committee is its chairman, and Mr. Arthur T. Upson, the representative of the U. S. Forest Service, has been elected secretary. Mr. Upson's address is care of the Forest Products Laboratory, Madison, Wis.

At present the Committee is made up of representatives of 15 organizations. Of its 16 members, 7 are classed as producers, 5 as consumers, and 4 as general interests.

LIBRARY NOTES AND BOOK REVIEWS

Kent's Mechanical Engineers' Handbook

KENT'S MECHANICAL ENGINEERS' HANDBOOK. By the late William Kent, M.E., Sc.D. Tenth edition rewritten by Robert Thurston Kent, M.E., editor-in-chief, and a staff of specialists. Leather and atholeather, 4½ × 7 in., profusely illustrated, $7; $6.

[The issue of a mechanical engineer's handbook is an interesting event to the entire profession. We are able to present reviews of the new "Kent" by Dr. Arthur M. Greene, Jr. and R. J. S. Pigott. EDITOR.]

THE tenth edition of Kent's Mechanical Engineers' Handbook, written originally by the late Wm. Kent, is rewritten by his son Robert Thurston Kent, M.E., and a staff of specialists. This new feature of having associates reponsible for definite parts of the work has greatly increased the value of this well-known reference book and gives it even more authority than it had in the previous editions.

Although the general subjects discussed in this new edition are about the same as in the former editions, the arrangement of the matter is changed greatly and the present form is much more convenient than that used previously. The plans of having each of the twenty-six sections of the book begin with a table of contents of the section, with its subdivisions, and having a bibliography in each section or subdivision, are both commendable. These will be very helpful to the users of the book.

The book has been brought up to date in many places, some references being made to articles appearing in the early part of 1923. Although many references to modern practice have been brought up to date it is to be regretted that in parts of the book old data have not been entirely eliminated. The section on steam boilers does not contain data on operation of certain stokers of the chain-grate type which should be in the hands of engineers. The form of modern firebox even with underfeed stokers on large boilers of the Stirling type is not mentioned. The same is true in a few other places.

This book like the "Kent Bible" of the nineties is fitted to answer most of the questions the mechanical engineer may ask in the operation of a plant he is laying out or managing. If he wants to know how large a turbo-generator has been operated and tested he can turn to the most excellent section on the steam turbine and get water rates and other data. By the method used in this section by Prof. A. G. Christie, its author, he can compare probable water rates under other operating conditions and find the total steam needed. The section on materials will give dimensions of pipe fittings, valves, and bends after the size of the pipe is fixed from the data on steam flow found in Section XIII. This section will give data regarding feedwater, heaters, economizers, condensers and other auxiliaries. If sizes of parts are to be investigated, this section and Section XVIII on machine design will give the necessary formulas and tests.

The strength of various beams and columns, the dimension sheets of cranes, the sections on lighting, heating and ventilation, and electrical engineering are all available to complete the design of the power house, while Section XXII on buildings will give data regarding foundations, walls, and reinforced-concrete and framed structures.

For general manufacturing the sections on power transmission, transportation, hoisting and conveying, friction, and lubrication will be of particular value. The section on power transmission has been rearranged by Mr. Kent and is much more helpful than it was in the earlier editions. The section on transportation is most excellent, dealing with locomotives, automobiles, and airplanes. The section on hoisting and conveying is well presented and gives data for all kinds of material-handling apparatus.

For shop work in manufacturing, for refrigeration, and for safety engineering as well as for marine engineering, sections are provided and the plant manager or designer can turn to these for most all of the data he may need in his work.

The matter dealing with materials is now arranged in such a manner that data relating to definite groups of materials are brought together in sections. General data are given in Section III on materials, with certain information regarding weights, safe loads, sizes, and tables of standards. Section IV is on strength of materials and contains much data from tests. Section V is an excellent one by Bradley Stoughton on iron and steel, while Section VI is on the non-ferrous metals and alloys. It is not easy to understand why certain data regarding cast iron and malleable iron were not placed in Section V in place of Section XX on shop practice.

Section IX on air includes data regarding the compression of air and its subsequent transmission. The data on fans and blowers are quite complete.

For those installing hydraulic apparatus, Section X on water hydraulics and water power and Section XI on pumps and pumping engines will be of interest. Mr. R. E. B. Sharp who has written the section on Hydraulic turbines has brought it up to the latest developments and this is true of all of the associates in their respective sections.

Section XII on fuels and combustion contains numerous tables of fuel data and also methods of calculating actions which may take place within furnaces.

The work has been increased in size from about fifteen hundred pages to almost twenty-three hundred pages. Much of this is due to new tabular data and to figures showing apparatus and curves giving test relations. Many figures of machine parts are shown to aid the designer as well as dimension and clearance sheets to give information for preliminary layouts. Some of the increase is due to the addition of test material in the various sections to make them of greater value.

In going over the text certain omissions have been noticed which are regretted by one who would like to see an all-inclusive book. The absence of any data regarding hyperbolic functions, spherical trigonometry, the use of semi-log paper, Rankine's methods of rectifying arcs, the strain formula of combined stress, and of modern data on flat plates was noted in this hasty review. Of course the editor of such a work must decide what is to be included and what is to be omitted, and the reviewer can only say that he wishes these things were in the book.

The book appeals and will be welcomed by the profession as a valuable adjunct to the books used at present.

ARTHUR M. GREENE, JR.[1]

The new edition of Kent's Handbook shows evidence of a great deal of painstaking work in the thorough revision that has been carried out. In the materials section the information on refractories and acid-resisting materials is useful, although it could probably be enlarged.

The extensive tables that have been one of the strong features of this handbook are still further enlarged. The treatment of much of the strength-of-materials section is new and excellent; the section on iron and steel is also very well done and has been given a much needed extension over the earlier material. The material on deaeration gives a good, though brief, expression of the present knowledge on the subject.

The section on non-ferrous metals and alloys contains considerable material that is simply unknown to the average engineer and is very hard to obtain, as but little real material is published on the subject. We certainly need more information generally on the behavior and properties of non-ferrous materials under high working temperatures.

In the section on heat, the transmission of heat in boilers and condensers is carried as far as the present chaotic mass of data will permit. The work of George A. Orrok on condenser tubes seems to be one of the very few attempts made to arrive at rational solution. The heat-insulation section is extended and well done.

The compressed-air section is full enough in treatment to be very useful; usually this subject is so badly underhandled as to be nearly

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useless. The use of Mr. Hagen's curves for fan capacities is commendable since this form of arranging performance data is about the most useful that has yet been devised. It would be a boon if all the manufacturers would use this form of curve, as it comes close to removing most of the mystery from the time-honored methods of treating fan performance, so that an *average* engineer can pick out the right blower.

The treatment of hydraulic turbines is much improved, and the free use of characteristic diagrams is of advantage. The material on centrifugal pumps immediately following gives a clearer idea of the similarity in the general theory.

The material on pulverized fuel, which occupies the center of the stage just at present, is necessarily very brief; the art is in such a stage of rapid, almost violent, development, that it is unsafe to attempt to tie down facts just now. Even the builders themselves are not sure of much.

The boiler and stoker material has been entirely rewritten, and at last the hand fire has been relegated to the place it belongs—obscurity. The treatment of performance from the point of view of the elder Kent's formula is interesting, although the writer personally prefers analysis on the basis of the input-output line, together with Lucke's method of analyzing heating surface and furnace efficiency.

The turbine section is exceptionally good; the difficult subject of stresses and critical speeds, and test data, is worthy of particular notice. The increasing use of thermal and Rankine efficiencies as a means of comparison instead of water rates has now become firmly established, and is largely used in this section.

The handbook as revised, contains an unusually large collection of tabular data, and should easily renew its long, continued popularity. Handbook arrangement is largely a matter of taste; two other methods have been employed in the writing of similar handbooks, but there is little difference in use, provided the indexing is good. The writer hopes that hand book publishers will one day have the courage to abandon the abominable little fat volume and adopt the 9 in. by 12 in. desk-book size that Fred Halsey employed for his Machine Designers Handbook. No one ever tries to carry a so-called pocket book in his pocket and the larger size gives opportunity for a much better scale of charts.

R. J. S. Pigott.[1]

The Life of Yarrow

Alfred Yarrow His Life and Work. Complied by Eleanor C. Barnes (Lady Yarrow). Longmans, Greene & Co., New York; Edward Arnold & Co., London, 1923. Cloth, 6 × 9 in., 328 pp., illus., $3.50.

THE life of Yarrow is a welcome addition to the too short list of inspiring biographical works about engineers of great character. Alfred Yarrow was great in that his outstanding mechanical ability did not outshine his sweetness of soul and the story of his life, simply and sympathetically told by Lady Yarrow, should be in every technical library.

As a schoolboy, Yarrow, bright, quiet and lovable, was proficient in mathematics and physics. He showed his mechanical genius at an early age in devices to perform some of his irksome houshold duties. While serving his apprenticeship, which demanded early rising, he constructed an arrangement which lighted the fire in his mother's room and in his own room ten minutes before the alarm clock sounded.

He attended all the scientific lectures that he could and, becoming interested in the telegraph, erected the first private telegraph line to London, crossing several properties and two public roads. The overcoming of popular objections to this line brought out the characteristics that seemed to underlie Yarrow's future success, for he later pointed out that the mechanical part of an enterprise frequently gives less trouble than the diplomatic side, and that "to show patience, courtesy, tact and, in the end, to obtain what is desired whilst remaining on friendly terms with all concerned—is the real art of business."

Toward the close of this apprenticeship, Yarrow designed a successful scheme of steam plowing. Steam plowing, however, was not suited to English conditions and his royalties were not large. Then he turned his attention to a steam carriage, but his activities were halted by the passage of a bill forbidding the use of steam on a road unless the carriage were preceded by a man carrying a flag.

Yarrow with a partner established his modest shops and after many vicissitudes built a steam launch which was successful. Thus he became established in marine work. His successes came fast upon each other from then on and his workmanship and design were in great demand for high-speed boats of all kinds. His ingenuity and resources were sought by many individuals and governments. Stanley sought his help to navigate the Congo; the British Government wanted boats to relieve Gordon at Khartum, and later he supplied torpedo boats. In the great war, destroyers were his principle contributions and valuable ones they were. Yarrow's life and work is a story of marine development over an exceedingly important period.

[1] Mech. Engr., Stevens & Wood, New York, N. Y. Mem. A.S.M.E.

Book Notes

Applied Personnel Procedure. By Frank E. Weakly. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 8 in., 192 pp., $2.

This book is not intended to be an exhaustive treatise on personnel administration, but rather to describe in concrete fashion a number of phases of personnel management with which the work of the author has made him familiar. He writes from long experience as a worker, as head of a personnel department, and as a general executive. The methods that he describes will fit both large and small organizations and have been tested by use.

Aufgabensammlung Zur Festigkeitslehre. By R. Haren. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 116 pp., diagrams, tables, $0.25.

In a volume of convenient pocket size and of small cost the author has collected sixty-six problems relating to the strength of materials, which he presents with complete solutions. The problems are those that occur frequently in machine design.

Automobile Shop Practice. By Edward K. Hammond and F. D. Jones. Industrial Press, New York, 1923. Cloth, 6 × 9 in., 306 pp., illus., $3.

This treatise takes up the manufacture of automobiles as carried on in this country, and describes the standards and special tools, machines, and processes used in many plants. The parts selected for description are those which require unusual tools and processes to obtain accurate work and large output. The authors believe the book will be of interest to those engaged in similar classes of work in other lines.

Automatic Sprinkler Protection. Supplement to second edition. By Gorham Dana. John Wiley & Sons, New York, 1923. Paper, 5 × 8 in., 40 pp., illus., $0.50.

A supplement to the 1919 edition of the author's book. Includes descriptions of new devices that have been introduced since that date, as well as several soon to be introduced.

Dictionary of Applied Physics, vol. 4; Light, Sound, Radiology. By Richard Glazebrook. Macmillan & Co., London, 1923. Cloth, 6 × 9 in., 914 pp., illus., diagrams, tables, 63s.

Volume four of this dictionary follows the plan of its predecessors, that is, it defines briefly the minor terms in its field and refers the user for further information to the extended articles by experts on general topics. These general articles are well-rounded summaries of present knowledge on the principal topics, provided with adequate references to the literature.

In this volume the subjects discussed are sound, light, and radiology. Special articles are included on crystallography, diffraction grating, the eye, glass, goniometry, graticules, infra-red transmission, interferometers, the kinematograph, lenses, light, luminous compounds, the microscope, navigational instruments, opthalmic apparatus, optical calculations, optical glass, periscopes, photographic apparatus, photometry, the pianoforte, polarimetry, polarized light, projection apparatus, the quantum theory, radiation, radioactivity, radiology, radium, range finders, shutters, sound, sound ranging, spectrophotometry, spectroscopes, spherometry, surveying instruments, telescopes, and wave-length measurements.

DIESEL AND OIL ENGINE HANDBOOK. By Julius Rosbloom. Technical Publishing Co., Los Angeles, 1923. Boards, 5 × 7 in., 376 pp., illus., diagrams, tables, $3.

The first five chapters of this handbook explain the principles of the Diesel engine, describe the pumps, governors and other auxiliary machinery, and give directions for testing. Chapter six offers detailed descriptions of a number of commercial types, and chapter seven discusses Diesel-electric ship propulsion. The book is intended as a reference work for practical men.

THE DYNAMO, ITS THEORY, DESIGN AND MANUFACTURE. Vol. 2. By C. C. Hawkins. Sixth edition. Isaac Pitman & Sons, New York and London, 1923. Cloth, 6 × 9 in., 322 pp., illus., diagrams, 15s.

In the opening chapter of this volume, which completes the study of continuous-current dynamos, a detailed analysis of the effect of armature reaction on the flux curve under load is given both for non-commutating-pole and commutating-pole machines. Succeeding chapters discuss commutation and sparking at the brushes, the heating of dynamos, dynamo design, working, and management. Two designs are worked out in full, to illustrate the application of the numerous formulas which have been given in the text.

ELECTRIC MOTORS; vol. 2, Polyphase Current. By Henry M. Hobart. Third edition. Isaac Pitman & Sons, London and New York, 1923. Cloth, 6 × 9 in., 384 pp., diagrams, $4.50.

Volume one of this treatise was reviewed recently. The concluding volume continues the account without interruption, giving special consideration to polyphase-current questions. The treatise is intended for the designer rather than for the student and is intended to show the state of the art at the present time.

MOTOR FUELS, THEIR PRODUCTION AND TECHNOLOGY. By Eugene H. Leslie. Chemical Catalog Co., New York, 1923. Cloth, 6 × 9 in., 681 pp., illus., diagrams, tables, $7.

An encyclopedic book on motor fuels. Dr. Leslie has not confined himself to the technology of the subject, but has included material of an economic nature and has made the contents of his book miscellaneous in some measure, so that it is of interest to the general reader as well as the student and the refinery engineer.

A special effort is made to present accurately the fundamental principles of physics, thermodynamics, and chemistry underlying the operations used in producing motor fuels, and also to review the research work in several fields where present knowledge is still unsatisfactory. Numerous bibliographies and tables are given.

Material-Handling Problems in Pier Design

(Continued from page 530)

time. The cost of getting things into and out of a car now was an enormous tax.

The author, in closing, said that as far as the stevedore question was concerned, he thought it was generally conceded that Philadelphia had about the highest grade of stevedores on the Atlantic coast. When it came to the question of installing machinery in pier sheds, the harbor authorities in the United States would hesitate a long while before doing so because usually such equipment was in the hands of the pier operators, who were generally careless in their use of publicly owned equipment. If some of the harbor authorities in the states actually operated the piers, as did one or two on the West Coast, he thought it would result in a greater extension in the use of mechanical equipment.

American dock authorities had hesitated in putting in pier machinery because of some doubt as to its efficiency and because they did not care to leave it in the hands of the operators.

The question of the two-decked pier had been raised by Mr. Birch. The cargo from the second deck was easily shifted to the first deck through gravity steel tubes. There was one pier in Philadelphia, owned by the Philadelphia and Reading Railway, which had second-deck tracks, and any two-deck pier which could be provided with tracks on the second deck would have a tremendous advantage over one not so equipped. Car elevators and also traveling cranes inside the pier shed had been considered, but the question of leaving that equipment in the hands of pier operators seemed to be a stumbling block, particularly with the harbor board that was not equipped properly with its own facilities, so to his mind the whole question simmered down to the desirability of a harbor board.

Determination of Chimney Sizes

(Continued from page 537)

In his closure, the author said that he believed that Professor Smallwood had overlooked one or two points set forth in the paper. It was obvious that the maximum capacity being independent of the height was based upon having the same conditions in all cases, including the mean temperature of the gases. If comparison was being made of two actual or proposed chimneys of different heights, the appropriate mean temperatures would be found as directed, so that this point was fully taken care of in the paper.

Leakage of air at breechings did not impair the method presented in the paper because the designer must naturally base his calculations on the weight of gases going up the chimney.

No one deplored more than the author the lack of information on chimney performance, or would more heartily welcome exhaustive research. However, Professor Smallwood would see on further consideration, that the method was not based on the slender support of the meager information now available but simply utilized what knowledge was so far available. As shown in the paper, further research would enable more accurate results to be attained by the use of the method. But to impugn the method because of lack of authoritative data was like suggesting that we discontinue the use of the micrometer until we have decided whether the inch or the meter is the better unit with which to graduate it.

In preparing the curves for finding mean temperature, the curve of temperature drop No. 1 in the Appendix was given the greatest weight since it was the only one in which the weight of gases was even approximately known. As the weight of gases in the Johns Hopkins tests was not given, no considerable use could be made of them except in a very general way.

Mr. Marsh had drawn attention to the variables to which consideration must be given, and these should always be borne in mind in determining chimney sizes. The various allowances which experience suggested were easily taken care of in using the proposed method.

Mr. Hopping had well empbasized the chaotic state of the art. If reliable results were desired, it was imperative that gas weights be used rather than boiler horsepower. When this was done, no trouble was experienced such as that caused by the different proportions of excess air in hand firing and modern machine firing.

In reply to Mr. Funk, the lack of experimental data affected the accuracy obtained by the use of any method of chimney computation, but in no way detracted from the value of the method itself. So far, friction had been based on volume passing and consequently on average velocity, and that really seemed to be the most convenient way, as it included both surface and fluid friction.

Replying to Professor Christie, the author said that further chimney experiments should include gas analyses at different heights, so that the draft loss and temperature drop within the chimney could be more definitely related to gas weight than can be done at present.

The author agreed with Mr. Uehling as to CO_2 readings and excess air, and could confirm his experience as to serious air leakage losses in very many plants. The use of CO_2 recorders should be increasingly encouraged; and in many cases, a CO_2 recorder connected to the chimney would be very valuable.

It was very interesting that Mr. Toltz had used the method in comparison with others. The advisability of having a simple method could not be gainsaid, and simplicity was an outstanding feature of the system.

Replying to Mr. Frost, the author said that he had found many overloaded chimneys that were not overloaded with useful work but with unnecessary air. Unless flues were airtight, the chimney would be unnecessarily overloaded.

Chimneys should in general be designed on a basis of gas weight. The curves based on boiler horsepower were only intended for approximate or preliminary work.